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EDITORIAL.

ITEMS AND NOVELTIES.

On the Distribution of the Heat Developed by Collision.—The following account of a very curious and striking phenomenon, observed during the forging of the 250 kilogram ingot of platinum-iridium, made for the standard meter, was communicated to the French Academy, on June 8th, by the distinguished Engineer and Metallurgist, M. Tresca. We take the translation given below from *Nature*, No. 255:—

Many of our colleagues who have become aware of a fact in thermodynamics which it has been in our power recently to observe, think it possessed of so great an interest that I ought immediately to announce it to the Academy. It is as follows:—

During the forging, which has been very successful, of the ingot of platinum-iridium for the standard meter, I at first remarked that it sometimes produced, under the action of the hammer, luminous streaks, having an oblique direction upon the lateral faces of the piece, when this, while cooling, was yet at the temperature of a dull red. I showed some of these effects to M. Fizeau, but they were then incomplete, and I have only lately succeeded in obtaining a good

observation of the phenomenon, and in defining its character with perfect certainty.

It is known that when a bar of metal is lengthened by means of a powerful hammer on an anvil of the same form as the head of the latter, each blow produces, above and below, a symmetrical contraction, the effect of which is to give to the bar the aspect of a series of projections separated by small level spaces.

At the time of the collision, these spaces, which are formed before and behind the impress of the hammer, upon the upper and the lower faces of the bar, are connected, at a certain moment, upon the lateral faces, by luminous lines passing from the one to the other, and presenting altogether the appearance of an X written in lines of fire. The phenomenon is only visible for a certain temperature of the bar which is being wrought, but then each blow invariably produces its effect, and, in consequence of the confused mingling of the imprints, we see the entanglement of these crossed lines which encroach upon each other. These brilliant bands appear at the same moment as the collision, but they do not disappear with it, and their continuance was sufficiently prolonged to enable us to count six luminous cross-bars visible at one time, although developed by six successive blows of the hammer.

I have been able, moreover, to get this persistence confirmed by several persons in the foundries of M. Farcot, who, with the greatest kindness, placed his services at the disposal of the Metric Commission for the execution of the work.

Although the lines of the cross-bars appeared to us all rectilinear, and although we could not compare them to anything better than two series of straight lines, parallel and intercrossed, we think it will be indispensable to determine their form more exactly by appropriate processes, and to discuss it with the greatest care.

It is well known that hammering develops heat in the bodies hammered; thermodynamics teaches us that these thermal effects ought to be regarded as the result of mechanical work or of *demi-force vive* exerted during the collision, but the precise place in which the calorific development is produced has not yet been noticed.

For ourselves, we do not hesitate to affirm that the zone which becomes luminous is that along which the matter mainly flows, at the moment when the change of form takes place, according to a law which we were enabled to discover in our previous researches in molecular displacements. If this first indication should be confirmed,

there would be thus obtained a more exact knowledge of the mode of distortion determined by the forging, and the phenomenon which we describe would evidently form a new scientific connection between thermodynamics and the question with which we ourselves are personally occupied under the title of "Flowing of Solid Bodies."

The phenomenon ought to be the same for all metals, and we have already ventured to hazard some considerations of the particular causes of the brightness which it presented in the case of platinum, and which has not, so far as we know, been yet observed in any other forging.

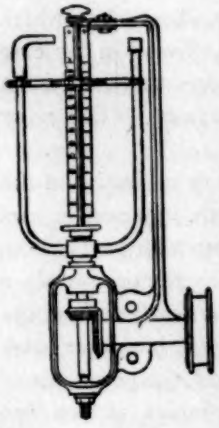
The exceptional hardness of the platinum-iridium, cooled to a dull red heat, requires, for an equal distortion, an amount of work at least equivalent to that of the forging of steel, and in consequence of the relative smallness of the calorific capacity of this alloy, this same work ought to be converted into calorific phenomena, more localized and more intense. Moreover, the material is more homogeneous than iron, and is notable for a kind of remarkable translucency which makes one believe that the eye can follow the shade of red to a certain depth. The effects, whatever they may be, are thus rendered more manifest, more especially as they are not accompanied by any exudation of foreign matter nor by any oxidation of the surface. All these circumstances are eminently favorable to the observation which chance permitted us to make, and which, once confirmed in the case of platinum, may certainly be renewed with other metals, although possibly in a more restricted manner than in the case of the alloy of MM. Deville and Debray.

We confine ourselves for the present to a summary indication of the principal fact, which appears to us to have a certain importance, and which consists in this appearance of luminous bands which arise from collision, and the position of which enables us to fix the precise place where is developed the heat which represents under another form the work done by motion; this fact is, perhaps, of a nature to open some new path for the researches, so carefully made, of the physicists of our epoch on all that touches on molecular mechanics and on the calorific actions which are connected with them.

The ingot of platinum has already been brought into the form of a bar with a square section of 4·50 m. in length; there will be a chance of continuing the same observations in the new operations of forging to which it will be submitted; the chance of renewing them may perhaps not again be offered.

Simultaneous Lighting of Street Lamps.—We see it announced in foreign journals that the city of Heidelberg has just introduced a recently invented system of instantaneously lighting the street lamps. By means of a small apparatus, very easily applied to each burner, the gas is made to light itself as soon as the pressure becomes sufficiently great. Towards midnight, when the pressure generally is diminished, certain parts of the flame are extinguished, while a portion remains lighted until morning, when the general distribution of gas ceases. It would appear that this apparatus is free from the great complication which has hitherto prevented similar devices from coming into general use.

Revolution Indicator.—Among the novelties in the Exhibition of the Franklin Institute, is a Revolution Indicator, invented and patented here and abroad by Mr. Ed. Brown of Phila. This instrument shows at a glance, by the height of a column of mercury the number of turns per minute made by a steam engine, without either counting or using a watch. It differs from the Engine Counter commonly used, which registers continuously the turns made per hour or day, but does not indicate the speed at any instant of time, simply by inspection, as does the Revolution Indicator. Its construction we will briefly describe by the aid of the annexed cut: The arm on the left is hollow, and is filled with mercury; it communicates with the central glass tube by means of a stuffing-box. The arm on the right is solid, and acts as a balance weight; it is connected with the mercury arm by a hollow strap. Upon revolving the instrument, the mercury falls in the central glass tube, and the speed per minute is indicated upon the scale-plate immediately behind it. The machine on exhibition has been running several weeks, attached to an engine driving the machinery, and appears to be remarkably accurate and sensitive, showing even a quarter turn in 60 revolutions. For the many engines which have to run at varying speeds for different operations, and also for engines controlled entirely by hand, the Revolution Indicator will be found particularly useful. When applied to marine engines, the accurate indication of this instrument will be somewhat influenced by the heel



of the ship, and possibly some of the mechanical devices in which clock-work is used may be preferred; though we are informed by Mr. Brown that its error at 20° is only 2 per cent.; and at 10° is less than one per cent.; and that its simplicity of construction, durability, and accuracy will make it more practically useful than instruments theoretically more perfect but also more complicated in construction.

W.

Statistics of Paper-making.—Some curious statistics relative to paper-making have been published by Rudel, of Vienna. It appears that there are 3,960 paper manufacturers in the world, employing 80,000 men and 180,000 women, besides the 100,000 employed in the rag trade; 1,809 millions of pounds of paper are produced annually; one half is used in printing, a sixth for writing, and the remainder for packing and for other purposes. The United States, with 3,000 machines, produces yearly 200,000 tons of paper, which for a population of 28,000,000, average 17 pounds per head. An Englishman consumes 11½ pounds; a German 8 pounds; a Frenchman 7 pounds; an Italian 3½ pounds; a Spaniard 1½ pounds; and a Russian only one pound annually, on an average.

Electro-deposition of Iron.—At the August Session of the Frankfort Society of the Physical Sciences, a memoir was read by M. Volger, upon the recent progress of electro-metallurgy and particularly upon the electro-deposition of iron. After giving a rapid review of the principal facts connected with the history of the galvano-plastic art, the memoir classes the directions of its development under three heads, as follows:—1st, where metallic forms are to be coated with other metals; as in electro-gilding, silvering, coppering, steeling, nickeling, etc. 2d, where the object is to imitate the plastic arts, and to take the place of metal casting. This special application is due to M. de Kress, who, at first at St. Petersburg, in 1845, and then successively at Frankfort, Offenback, Carlsruhe, Darmstadt, and finally at Mayence, has organized establishments in which the art has been carried to the highest perfection, as well for the smallest objects of nature as for the grandest works of art, among which may be mentioned the three colossal figures of the printer's monument at Frankfort, and the small tablets representing agricultural subjects, which are his especial invention. 3d, where the reproduction of works of art is the object; that is to say, the duplication of engraved plates, and the

preparation of electrotypes. It is in this last class that the greatest progress has been made.

So far as the electro-deposition of iron is concerned, it is now nearly forty years since M. Peligot succeeded in reducing iron chloride by passing hydrogen over it. In this way he obtained metallic iron in octohedral crystals and succeeded in making some small malleable plates. In 1846, M. Boettger made the first attempts to decompose iron chloride by the voltaic current, and obtained excellent results. He soon perceived, however, that a mixture of ammonio-ferrous sulphate and of ammonio-ferrous chloride, was more advantageous for electro-deposition, and he prepared it very simply by dissolving together two parts by weight of ferrous sulphate and one of sal ammoniac. For the anode he used a plate of sheet iron, and a plate of tin-plate iron for the cathode. In this way, M. Boettger made with great perfection, a coin of iron. The specimens of iron thus made were extremely hard and steely, but were also, unfortunately, very brittle, and so fragile that they broke in pieces in taking them from the mould. Hence no applications of this process on any industrial scale were possible.

In 1859, M. Jacquin rendered the above process capable of useful application, by making known a method of steeling engraved plates, that is to say, of depositing an excessively thin layer of iron upon these plates, without at all impairing the fineness and the delicacy of the engraving, but communicating to the copper thus protected a hardness comparable to that presented by a plate of steel. For this process, the method of electro-deposition proposed by M. Boettger is the best thus far discovered and has been generally adopted

Very recently, M. Klein, of St. Petersburg, has remarkably perfected the electro-metallurgy of iron. Even in 1868, he had submitted to the Academy of Sciences of St. Petersburg some excellent results which he had obtained with a solution of ammonio-ferrous sulphate, a Meidinger battery, and a sheet iron plate used as the anode. M. Klein prepared in this way, by electro-precipitation, not only entire plates of this sheet-like iron, from the hardest to the softest, for the purpose of reproducing engraved copper plates, which united to the advantages of softness, for the purpose of engraving, of copper plates, that of hardness in the steely iron, for printing; but also plates showing its availability in the working of iron. In all cases

however, the iron precipitated by M. Klein is very sharp and brittle, the cause of which he found to be hydrogen which had combined with it and which had lessened its specific gravity to 7·675, that is to say, a little above that of rolled iron. By annealing, however, this hydrogen may be expelled and the iron may thus be given a density of 7·811, surpassing that of forged iron; it is now perfectly malleable, eminently flexible and elastic, and like sheet steel, may be welded; in a word it possesses all the characteristics of an excellent forged iron.

M. Volger placed before the Society some of these steel plates taken from engraved copper plates, prepared by M. Klein, a block made of scrap welded together, forged, filed and polished, and also a shield of the size of a plate, representing in raised work, the Battle of the Amazons in rare perfection. M. Klein has prepared a similar plate weighing seven and a half kilograms.

The highest and most important use of electro-siderurgy is in its employment in stereotyping, especially in reproducing plates from which bank-notes are to be printed, postage stamps and the like-colored objects, since the iron will stand well without injury the mercurial colors so fatal to copper, to type-alloy and to other metals.

Bibliographical Notices.

THE CONSTRUCTION OF MILL DAMS. 8vo., pp. 336. *Springfield, Ohio*, 1874. *James Leffel & Co.*—As stated in the preface, a considerable portion of the matter of this book has appeared from time to time in *Leffel's Illustrated Milling and Mechanical News.* After being carefully revised and considerable new matter added, it is now republished in a handsome volume of more than three hundred pages, illustrated with numerous full page engravings. In this form it must prove, we think, of great value to builders of dams. The examples given cover nearly all the conditions under which mill dams are built, the materials which are used, and the variety of designs and expedients adopted to overcome natural difficulties. There is also much useful information concerning the building of embankments, and the measurement of streams and water supplies. The easy style and the absence of abstract formulæ will make the work of especial value to the non-professional worker, while the clear statistical statements of some of the largest works of this kind in America cannot fail to be useful to the professional engineer. K.

Franklin Institute.

HALL OF THE INSTITUTE, Oct. 21st, 1874.

The meeting was called to order at the usual hour, with the President, Mr. Coleman Sellers, in the Chair.

The minutes of the stated meeting held September 16th, were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at their stated meeting, held October 14th, the following donations to the Library had been reported, to wit:—

[See the JOURNAL for October, 1874, pp. 234–235.]

The Actuary likewise reported the minutes of the several standing committees.

The President next announced a paper by Mr. Alexander E. Outerbridge, on "The Spectroscope in its application to Mint Assaying." The paper contained the results of an investigation undertaken by the author, to determine the possibility of establishing a practical method of quantitative spectrum analysis upon the basis of Lockyer's discovery that, under certain conditions, the lines of the metallic spectra do not entirely cross the field of vision, but break in the middle. The paper was amply illustrated with the aid of projections upon the screen. The conclusions reached were unfavorable to the practicability of the process. The paper was discussed by Messrs. Nystrom, Wahl, and the author.

The President next announced a paper by Mr. John E. Caldwell, of Pittsburgh, "On Hemphill's Balanced Slide Valve," being a description, illustrated by diagrams, of a recent invention of this character. The question as to the originality of certain novel features claimed by the inventor was discussed by Messrs. Le Van, Wiegand, and the author.

The Report of the Secretary next followed, which, amongst other matters of a technical nature, gave a description of the Automatic Gas Regulator of Messrs. Allen & French, which was exhibited at the meeting.

The President made the announcement that he had been called upon by Mr. Sterne, of Thompson, Sterne & Co., limited, Westminster, England, who had shown him certain samples of ground discs of hard steel (the President therewith exhibited the specimens), which

had greatly interested him on account of their perfection. He had asked the loan of the discs, seven in all, $2\frac{1}{8}$ inches diameter, and ·027 inch thick, to show the members at this meeting. The seven plates placed one on the other, appear to be one solid disc of steel. To grind these plates, a magnetic chuck had been designed. This chuck, attached to a lathe spindle, is magnetized by a Gramme machine, and held the plates firmly while being operated on by the grinding machine. Mr. Sterne had stated also, that chucks of a larger size have been used to hold iron plates during the turning or planing operation.

The President next read a communication from Mr. William P. Tatham, in relation to the life-boat of the U. S. Government, now in the Institute Exhibition, and read the following resolution, which Mr. Tatham had requested him to make on his behalf:

Resolved, That a committee be appointed to examine and test the life-boat now in the Exhibition, and to report what modifications, if any, should be made to adapt it for our coasts, and also to examine the question of the best construction of life-boats for ships at sea.

The resolution was duly seconded and passed, and the President appointed the following members to serve upon the committee:—Messrs. G. N. Tatham, Charles S. Close, and John C. Trautwine.

Messrs. Burleigh, Close, Bullock, Orr and Le Van then occupied the floor, upon the question of admitting to the Exhibition, under certain regulations, the pupils of the public schools, and of certain charitable institutions, such as the Northern Home for Friendless Children, and the like. The whole subject was finally referred to the Committee on Exhibition.

Mr. Hector Orr next called the attention of the meeting to the recent death of one of the prominent members of the Institute, Mr. John W. Murphy, and in appropriate words moved an invitation to Mr. Le Van to present to the meeting an account of the life and services of the deceased. Mr. Le Van thereupon presented the following

BIOGRAPHICAL NOTICE OF JOHN W. MURPHY, C. E.

By W. Barnet Le Van.

It is with sentiments of more than ordinary regret I have to announce the death of one who has been a member of this Institute and has for many years past occupied a prominent position in connection with engineering science, and who, both by his writings and his works,

has left an ineffaceable imprint upon the times in which he lived. I have reference to John W. Murphy, C. E., who on Sunday, September 27th instant, after a brief illness, closed an active and useful life, although having only attained the age of 47 years.

Mr. Murphy was born at New Scotland, in Albany County, New York, in the year 1828, his father being a farmer. During his youth he showed great proficiency for mathematics and surveying, and was placed with Mr. Wm. Henry Slingerland, a noted surveyor, and at the age of 15 years received a certificate from him that he was fully accomplished for the above profession, which bears date, Bethlehem, New York, November 15, 1843.

In April, 1847, at the age of 19, he entered Rensselaer Institute, at Troy, N. Y., from which he graduated in April, 1848, taking two degrees, B. N. S. and C. E. He was the most industrious student of his class. In addition to the studies necessary for graduation, he completed successfully the mathematics of the post graduate course. The extra labor cost him a severe fit of illness, which followed immediately upon his graduation.

In 1849 he was appointed Second Assistant of the Engineers in charge of the Western Division of the Erie Canal, under Squire Whipple. While connected with Squire Whipple, Mr. Murphy and he first introduced "Pin Connections" in Bridges, a most important step forward in Bridge Engineering. Zerah Colburn, in a paper read by him before the British Institute of Civil Engineers, some years ago, refers to and upholds the claim of Squire Whipple and Mr. Murphy to the introduction of this now almost universal connection in American bridge building.

About this time he designed a Suspension Bridge at Wibir Hill, across the Mohawk. This bridge had a vertical truss, to insure *stiffness*, the plan being original with him.

From 1851 to 1852 he was employed at Montgomery, Alabama, in erecting levees on the Alabama river.

In 1853–54 he built, under contract, a wooden bridge from the designs of F. C. Lowthorp, C. E., at Easton, Pa. It was obligatory by his contract that the work should be executed during the spring and summer months; he found that the rafts that came floating down the river made it impossible for him to erect this bridge in the ordinary manner, that is to say, by placing trestles or false works in the stream, upon which the superstructure would ordinarily be erected.

He devised the following novel plan: Wire ropes were suspended from pier to pier, and placing stanchions upon them, braced in the usual way, and made a temporary bridge, upon which he erected the main superstructure, by which means the rafts passed freely underneath, without danger to his workmen or the raftsmen, who were obliged to float upon the high currents of the Delaware.

In 1856 he began to build iron bridges, on the plan known as the Murphy-Whipple plan. The first of these was on a branch of the Lehigh Valley Railroad, and the second a double track bridge for the Beaver Meadow Railroad.

It was at this time he insisted upon determining the limit of elasticity of bridge iron as being of quite as much importance as the breaking weight, and urged the necessity of testing the different irons; he devised and constructed a testing machine. The idea was considered rather novel at that time by most engineers.

Between 1855 and 1857 he was in partnership with George W. Plympton, at Trenton, N. J., under the firm name of Plympton & Murphy. The financial panic of the latter year put an end to their bridge building. He then took up his residence in Philadelphia, and was connected with the erection of a large number of bridges, of which he was the designer.

In 1859, in company with Levi Line, George B. Algernon and Percival Roberts, under the firm name of A. & P. Roberts & Co., he being the Chief Engineer, and I. P. Morris & Co. the builders of the iron work, he erected for the U. S. Government seven bridges for Beal's Wagon Route, on the Plains, four of which were 100 feet, and three 50 feet spans, on the Whipple plan, with cast iron arches. Also one of 65 feet span, with draw, over Frankford Creek, Bridesburg; one of 50 feet span on the Foglesville Railroad, one of 165 feet span, on the Murphy-Whipple plan, over the Delaware, at Easton, for the Lehigh Valley Railroad; one of 160 feet span, for the Illinois Central Railroad, under Gen. McClellan; two of 125 feet span over the Jordan Creek, at Allentown, for the Lehigh Valley Railroad Co., and one of 50 feet span, for A. Campbell & Co., over the canal at Manayunk. This bridge, when finished, was remarkable for its lightness, being sent to its location in a furniture car, but they refused to receive it, as they did not believe it would answer the purpose intended. The bridge was, nevertheless, erected, and is standing at this present time in as good condition as when erected, and for the first six years

carried a 4-inch line of shaft, which transmitted over 50-horse power to the opposite side of the canal; also a 4-inch water main, and the carriage of the products of their large mill, of 20,000 spindles.

During the years 1860 and '61 he occupied the position of Chief Engineer of the City of Montgomery, Ala., but upon the breaking out of the war, although offered great inducements to remain and cast his lot with the Confederacy, his love for the Union was so paramount in his mind that in escaping from the surveillance under which he was placed until he freely assured them of his choice, he was compelled to leave, forsaking behind him all of his instruments, papers, library, and other valuable interests.

In 1863 he was called upon by the U. S. Government to replace a bridge over a branch of the Gauley River, in West Virginia, destroyed by General Wise, General Rosencrans having command in that department. Mr. Murphy agreed to erect it in twenty-five days. He immediately proceeded to work, and on the twenty-third day it was ready for use. It was a suspension bridge, 520 feet in length, 10 feet roadway, consisting of three spans, supported by eight cables. There was some doubt in the mind of the commanding officer that it would answer the purpose for which it was erected, and so intimated to him. To test it properly and convince those in authority, he asked that a battalion be ordered to make a charge over it, which was done, to the satisfaction of the General in command. It was thus proven that their fears were groundless, and it afterwards passed and repassed the whole command as long as they occupied that portion of the country. A change of base put it into the possession of the Confederates, who burnt it down.

In June, 1864, he designed and erected the Union Hall, in connection with the building for the U. S. Sanitary Fair, in Logan Square, in forty days, he making the greater part of the drawings at his home at night. The truss arch of this building was purchased by the Pennsylvania Railroad Company, and is still used at the depot of departing trains for New York and Pittsburgh.

In the fall of 1869 he designed the Pipe Aqueduct crossing the valley of the Wissahickon at Valley Green, for the supply of Germantown, so as to avoid forming a trap, which was approved by Fred. Graff, Chief Engineer of the Water Department, December 7, 1869, and a contract entered into by him for its erection, which was finished during the summer of 1871.

This structure consists of two lines of flange pipes, 20 inches inside diameter, placed parallel to each other, at a distance of 14 feet from centre to centre, forming the compression chord of the aqueduct; each line of pipe is supported by two lines of wrought iron links, 10 square inches in section, attached to lugs cast upon the end pipes of each span; from these, vertical wrought iron columns 5 inches diameter, supported the pipes, entering into bosses upon the under side of the same; the whole is placed upon three piers, formed of four columns, each 8 inches diameter, stiffened by cross-ties and horizontal wrought iron beams. The aqueduct consists of four spans, each 165 feet 9 inches in the clear. The piers are 7 by 14 feet, resting on stone foundations.

In this structure he carried out the principle he introduced in 1854, in the erection of the bridge at Easton, over the Delaware, for supporting his superstructure, in place of trestle or false works, as is ordinarily used.

But his name will, perhaps, be best perpetuated in the new structure at South street, which is rapidly approaching completion. Under the authority of the commissioners appointed to carry on this public work, he received the contract for $770,000, and commenced his labors in 1870. The rapid construction of the work has been greatly interfered with by events that scarcely any contractor has been called upon to undergo. In attempting to found the piers on the western approach, he was arrested at the instance of the railroad companies, and bound over to court, for interfering with the passage of trains, and kept under bonds for a long period of time, until the assumed rights of the railroads were harmonized in the construction of the bridge by the commissioners.

On the eastern side the land was not condemned and jury appointed to assess damages until twelve months after signing of the contract, and some fifteen months' detention in the work was thereby occasioned, Mr. Murphy being arrested twice and placed under bonds for trespass, before all the conflicting interests were settled.

In the river delays occurred again by the passing tugs and tows, and severe loss was sustained by the wilful destruction of three of the pneumatic piles by a tug boat, which occasioned some three months' delay, the pier having been bolted to the bed rock of the river and filled with masonry, all of which had to be removed, and repairs made, and replaced.

The large amount of masonry to be laid across an alluvial deposit of earth, demanded extra caution and care in the construction thereof, and considerable time was required to secure permanent foundations for the magnificent line of arches which grace the western approach. The South Street Bridge commences at the intersection of Chippewa and South streets upon the eastern side, to the high ground of the Almshouse property beyond the Junction and West Chester Railroads on the west side of the river, connecting with Spruce street.

The entire length of the structure is 1934 feet 7 inches, consisting of two fixed spans 195 feet 8 inches each, and a draw 198 feet 2 inches in length, supported by a pier at each end of the draw and one in the centre to receive the pivot. Each end pier is formed by two columns of cast iron 8 feet in diameter, cast in sections ten feet in length, 1¾ inches thick, with inside flanges 2¾ inches wide, by 1¾ inches thick at top and bottom of each section. The flanges are pierced with holes 5 inches apart, from centre to centre, to receive 1¼ inch bolts. The bottom flange is omitted in the section forming the bottom of the column, when in position, for greater facility in penetrating the soil. This end is not beveled, as is generally done, but left square, so as to retain the full value of the thickness of the column for a bearing surface on the rock, each section weighing about 14,600 pounds, averaging seven sections to each column.

The pivot, or centre pier, is formed by a cluster of nine columns, a six feet column in the centre supporting the pivot of the draw, and a surrounding circle of eight columns 4 feet in diameter, carrying the track on which the draw revolves. This circle is 36 feet in diameter from out to out, while the pier columns are placed with their centres directly under the main chords of the bridge, making them 36 feet apart from centre to centre, and at right angles to the centre line of bridge, giving an opening of 77 feet on each side in the clear. The section of six feet columns average 10,800 pounds, and the four feet columns 6800 pounds each. These columns were cast from Government cannon, originally made from cold-blast charcoal pig, being an unexceptionable material for this purpose.

These columns were placed in position by the use of compressed air, by the plenum pneumatic process, as first adopted by Triger, in sinking a coal shaft on the Run Loye, in France, through a stratum of sand, &c., overlying the coal stratum, at the Bridge of Macon, and by John Hughes, at the Rochester Bridge, in England, and at Kehl,

on the eastern border of France, in a railroad bridge across the Rhine, but more commonly known in this country as the pneumatic process.

In sinking these "pneumatic cylinders," Mr. Murphy introduced a more economical air-lock than was heretofore used, which enabled the workmen to pass from the normal atmosphere outside the column, to the denser atmosphere of the interior, and to prevent the escape of the compressed air while so doing. He also adopted, for the first time, brackets in sections, and extending clear around the whole inner circumference of the bottom of the column, and secured to its side by four 1¼ inch tap bolts; and to the rock by four bolts 18 inches long, with fox wedges at the lower end, and thread and nut on top, thereby adding much to the stability of the work. This was necessary on account of the small amount of holding ground for the cylinders, overlying the bed-rock.

The bed of the Schuylkill, at the site of the bridge, is a micaceous gneissic rock, undulating in surface, with overlying strata of sand, and tough, compact mud, intermingled with gravel and small boulders. Lying directly on the rock, considerable quantities of driftwood were found, its appearance evincing great age and a long occupation of its present position. The average depth of this bottom material is about thirty feet at the western pier columns, diminishing to only five feet at the eastern pier. At the draw the thickness is about eighteen feet.

The width of the approaches is 55 feet, consisting of carriage-way 35 feet wide, and two footways 10 feet wide on each side.

The eastern approach is 518 feet 10 inches in length, consisting of 363 feet 6 inches of broken range ashler retaining wall, of sandstone, and 114 feet 6 inches being three conoidal or flue arches of original design, composed of brick with stone rings and a granite abutment of 40 feet 10 inches, with pilasters and doric capitals.

The western approach is 826 feet 6 inches in length, consisting of 87 feet 4 inches of regular range ashler retaining wall of granite, and three trussed spans 244 feet 9 inches in length, supported by eight wrought iron columns over the Junction and West Chester Railroads, to an abutment of 62 feet 4 inches in length, and thence by nine brick arches of 43 feet 6 inches span, from centre to centre, with stone rings, 391 feet 3 inches long, with granite piers, to a granite abutment of 40 feet 10 inches, same character as eastern abutment.

Having referred to Mr. Murphy as an engineer, I will also speak

of him as an author. He possessed the pen of a ready writer, and his contributions to the scientific literature of this country extend over a period of twenty years. He was a contributor to a great number of the scientific periodicals, and has read before this Institute a number of papers on different scientific subjects. His writings were distinguished by a very high order of style, and always forcible, practical, and convincing in argument, and, withal, agreeable and happy in his illustrations. At the time of his death he was engaged on a paper for this Institute, entitled "Bridge-Building Considered Normally," the first part of which will be found in the October JOURNAL, of 1873, page 242. He was an excellent speaker and a good conversationalist, and a most entertaining companion, being gifted with a retentive memory, he having during his life and in his intercourse with the world, come in contact with a great variety of persons. He was also a good musician, and wrote music with rapidity and harmony.

This man of great attainments has passed from among us, and his place knows him no more. His kindly genial face, and, above all, his warm hearted, generous, and impulsive nature, will long be remembered by those—and they are many—to whom for so many years they have been familiar. Mr. Murphy was twice married. By his first wife he had two children, a son and a daughter, whilst by his last he had no children. His children and second wife survive him. His death took place at his residence in Thirty-second street, in this city. The brief time at my disposal since his death, has been hardly sufficient to enable me to do justice to the memory of one who has played so prominent and varied a part in the history of engineering science as has Mr. Murphy. I feel assured that my shortcomings will not affect his merits, from which they cannot possibly detract, nor will my deficiencies impair the brightness of the memory of one whom, to know was to appreciate and respect, and whose character and attainments can cease to be admired only when they cease to be remembered.

Philadelphia, October 20, 1874.

The Secretary moved that the thanks of this meeting be tendered to the Directors of the German Society, for their courtesy in providing chairs for the meeting. Carried.

On motion, the meeting adjourned.

WILLIAM H. WAHL, *Secretary.*

Civil and Mechanical Engineering.

ON THE THEORIES OF STEAM-BOILER EXPLOSIONS.

By Dr. Ferdinand Fischer.*

Apart from the use of bad materials, from bad construction, and from bad workmanship, the alleged causes of steam-boiler explosions may be included under the following heads:—

1. Excessive pressure of steam.
2. Electrical action.
3. Explosive gases.
4. Spheroidal state.
5. Superheated water.
6. Sudden relief of pressure.
7. Shocks to the boiler.
8. Overheated plates.

1. *Excessive pressure of steam* is, only in the rarest cases, the direct cause of an explosion; that is to say, of so sudden a destruction of the boiler that it is torn into fragments, and these are projected to a distance. Such a violent result as this can have its immediate cause, according to Grashof,[1] only in the sudden conversion of a large amount of heat into work.

That boilers may, under certain conditions, sustain a very high steam-pressure notwithstanding the fact that they are so far damaged that upon inspection they may be perforated in various places by the blows of a small hammer, is well known.[2] The experiments of Andraud,[3] on the other hand, have shown that an iron boiler of 100 liters capacity, whose walls were two millimeters thick, could be burst

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1. *Zeitschrift für die gesammten Naturwissenschaften*, 1872, 103.

2. *Zeitschrift des Vereins deutscher Ingenieure*, 1869, xiii, 350.

3. *Dingler's Polytechnisches Journal*, 1841, lxxix, 316; *Zeit. Ver. Ingen.*, 1869, xiii, 152, 569.

by condensing air into it to a pressure of seventy-five atmospheres, but could not be exploded.

Moreover, the experiments of Stevens[4] and of the Commission appointed by the United States Government,[5] have proved that an excessive pressure of steam in a boiler in which there is a weak spot, causes simply a rent (or where the plates are brittle a piece may be blown out); while, when the plates are uniformly strong throughout, this pressure will, in all probability, cause a violent explosion.[6] The fracture of a boiler may, therefore, by suddenly relieving the pressure, be the occasion of its explosion; its rupture occasioning this explosion.

2. *Electrical action.* Andraud[7] maintains that by the evaporation of the water in the boiler, electricity is developed, which, under certain conditions, becomes capable of exploding. He therefore recommends the attachment of lightning rods to boilers. Jobard[8] is of the opinion that the electricity produced by the evaporation is sometimes collected on the numerous brass tubes serving as flues, as in a Leyden jar, and so produces a most destructive explosion. Tassin,[9] Wilke,[10] Hofmann,[11] Schiele[12] and others[13] also believe that electricity plays an important part in steam-boiler explosions. These suppositions, however, all of them evidently overlook the important fact that the electricity which may possibly become free can collect only upon the outer surface of the boiler, and that this surface is never insulated. Moreover, it is not easy to see how it is possible for electricity itself to explode.

Lardner[14] explained the explosion of a locomotive by attributing it to a stroke of lightning which so heated the boiler walls as to cause a sudden and violent evolution of steam, and so produced an explosion;

4. *Dingler's Polyt. J.*, 1872, cciv, 4.
5. *Dingler's Polyt. J.*, 1873, ccxi, 412.
6. *Dingler's Polyt. J.*, 1839, lxxiii, 401; 1841, lxxix, 234; 1842, lxxxiii, 10; 1867, clxxxvi, 84; *Zeit. Ver. Ingen.*, 1870, xiv, 215; Wiek's *Illustrirte Gewerbeztg.*, 1861, 56.
7. *Dingler's Polyt J.*, 1841, lxxix, 316; 1855, cxxxvii, 24.
8. *Dingler's Polyt. J.*, 1841, lxxix, 233.
9. *Dingler's Polyt. J.*, 1841, lxxix, 234.
10. *Zeit. Ver. Ingen.*, 1866, x, 571.
11. *Zeit. Ver. Ingen.*, 1868, xii, 235; *Dingler's Polyt. J.*, 1867, clxxxvi, 84.
12. *Zeit. Ver. Ingen.*, 1866, x, 569.
13. *Zeit. Ver. Ingen.*, 1862, vi. 358; 1872, xvi, 786.
14. *Dingler's Polyt. J.*, 1845, xcv, 249.

a statement, the possibility of which may be questioned. Not more probable is the hypothesis of Wilder,[15] that boiler-explosions are caused by the suddenly setting-free of caloric.

3. *Explosive gases.* Some years ago Perkins[16] asserted that explosions were frequently caused by the decomposition of the water of the boiler into its constituent gases; and Mackinnon[17] maintained that hydrogen was set free in the boiler by contact of the water with its highly heated walls; and that then, by opening the throttle-valve, air is allowed to enter, which mixing with the hydrogen, becomes ignited by the red hot plates and causes an explosion. Du Mesnil[18] is of the opinion that hydrogen is set free by the decomposition in the boiler of water and of oil-vapor, and that this coming in contact with the oxygen contained in the feed-water, forms an explosive mixture, which, being ignited by the plentifully generated electrical sparks, explodes and bursts the boiler. Schiele[19] believes that electrical sparks are produced in the boiler by the ebullition—just as lightning is produced in the clouds—and that these inflame the mixed gases and cause the explosion. Jobard[20] asserts that either water is decomposed by the ignited boiler-plates, or that, by the decomposition of the organic matter contained in the feed-water, a sort of fire-damp is generated. If now the tube of the feed-pump does not constantly dip below the surface of the water supplied to it, air is pumped into the boiler (?) and an explosive mixture of gases is thus formed; this, being ignited either by electric sparks or by the glowing organic matter within, causes the explosion of the boiler. Hipp[21] even maintained that the formation and ignition of explosive gases is the sole cause of boiler explosions; but his arguments on the point have been satisfactorily answered by Grashof.[22]

The investigations of a Commission appointed some time ago by the Franklin Institute of Pennsylvania,[23] have shown that water con-

15. *Dingler's Polyt J.*, 1850, cxv, 87.
16. *Dingler's Polyt. J.*, 1824, xv, 138.
17. *Dingler's Polyt. J.*, 1832, xliv, 228.
18. *Dingler's Polyt. J.*, 1842, lxxxiii, 7.
19. *Zeit. Ver. Ingen.*, 1866, x, 569.
20. *Dingler's Polyt. J.*, 1842, lxxxiv, 158; lxxxvi, 252; 1844, xciv, 344; 1846, cii, 407.
21. *Zeit. Ver. Ingen.*, 1857, xi, 635, 753; 1869, xiii, 758; Hipp; die Gas bildung als Ursache der Dampfkesselexplosion (Baedecker, Coblentz).
22. *Zeit. Ver. Ingen.*, 1867, xi, 762; 1869, xiii, 765.
23. *Dingler's Polyt. J.*, 1836, lxi, 418; 1849, lxxi, 269.

tained in a red hot boiler whose walls are clean but not polished, is not decomposed. And Schafhautl[24] has proved that one volume of oxyhydrogen gas will no longer explode, if mixed with 0·7 of a volume of steam. Parkes[25] indeed states that an inflammable gas is evolved during the blowing off of a highly heated boiler, which on opening the manhole, bursts into a flame; but, notwithstanding this, there can evidently be formed, during the hours of work, only the smallest possible traces of hydrogen. Even were large quantities of combustible gases evolved within the boiler, these would be so much diluted by the steam present, that even with a sufficient access of air and in presence also of ignited boiler plates—the hypothesis of electric sparks is completely absurd—an explosion of any magnitude is not to be thought of.

Wolf and Taylor[26] assume as a cause, the explosion of gaseous products within the flues. If the stoker in charge, either at noon or at night, covers the glowing coal with a thick layer of slack or ashes, and closes the damper in the chimney, gases are formed, according to Jobard[27], which, when the fire-door is again opened and the fire is stirred, explode and destroy the boiler. Both Hänel[28] and Wabner[29] also emphasize the danger arising from such explosions in the fire-passages.

That inflammable gases may collect in the flues, is a well known fact; but that the explosion of these gases is sufficiently powerful to tear in sunder the boiler, is very improbable. Nevertheless, under certain conditions, especially in connection with the causes mentioned under 1, 5, and 7, these gases may be the indirect cause of a boiler explosion. At all events, prudence demands that after an intermission in the work, the damper should first be opened, and then the fire-door, so that in this way the explosible gases may be carried off.

4. *Spheroidal State.* Boutigny[30] regarded the so-called spheroidal state of the water in the boiler, as the chief cause of its explosion[31]. A white-hot metallic ball plunged into soap-water becomes immediately

24. *Dingler's Polyt. J.*, 1839, lxxi, 351.
25. *Dingler's Polyt. J.*, 1842, lxxxiii, 21.
26. *Dingler's Polyt. J.*, 1827, xxiv, 295; xxv, 279.
27. *Dingler's Polyt. J.*, 1861, clix, 394.
28. *Zeit. Ver. Ingen.*, 1867, xi, 164.
29. *Dingler's Polyt. J.*, 1870, cxcvii, 377.
30. *Dingler's Polyt. J.*, 1842, lxxxiii, 457; 1845, xcvi, 209; xcviii, 427; 1848, cvii, 241; 1851, cxix, 239, 464; 1850, cxvii, 394; 1851, cxxi, 48, 55, and 78.
31. *Zeit. Ver. Ingen.*, 1869, xiii, 150 and 567.

surrounded with an envelope of vapor, and produces no hissing noise either at the time of immersion, or for some seconds afterward. But when this envelope of steam disappears from the ball by reason of its cooling, the water comes in contact with the hot ball, a sudden evolution of steam takes place, amounting almost to an explosion, and the vessel is generally shattered. A. W. Hofmann[32] has transformed this inverted Leidenfrost's experiment into a beautiful demonstration for the lecture-room. Barret[33] thinks that impure water in steam boilers takes the form of hollow (?) spheres; and that these exert, on bursting, a very strong tension. Normandy[34] indeed believes that he has actually observed such a spherical condition of the water in a steam-boiler. But it is very improbable, nevertheless, that such a phenomenon can occur frequently in a boiler, or can lead to its explosion.

5. *Superheated Water.* Dufour[35] has shown that drops of water ten millimeters in diameter, enclosed in oil, can be heated to 175° C., without the formation of steam. He has proved, still further, that under diminished pressure, considerable superheating may occur. Donny[36] succeeded in heating water, free from air, under the ordinary pressure, to 135° C. The corresponding observations of Schmidt[37], Krebs[38], Tyndall[39] and Gräger[40], are well known.

Dufour concludes from his experiments, that, during the period when the machinery is still, the steam-tension becomes lessened by the cooling of the steam-space, while the water continues to maintain its high temperature. By agitation, by opening the throttle, and the like, a sudden almost explosive boiling takes place, accompanied with a tumultuous formation of steam, which may prove destructive to the boiler. Heinemann[41], Kirchweger[42], Ruhlmann[43] and Reiche[44] question

32. *Berichte der deutschen chemischen Gesellschaft*, vii, 535.
33. *Ber. Berl. chem. Ges.*, v, 814; *Mittheilungen des hannoverschen Gewerbevereins*, 1873, 102; *Zeit. Ver. Ingen.*, 1866, x, 155.
34. *Dingler's Polyt. J.*, 1854, cxxxiii, 329.
35. *Dingler's Polyt. J.*, 1864, clxxiii, 266; *Poggendorff's Annalen*, cxxiv, 206.
36. *Dingler's Polyt. J.*, 1847, ciii, 75; cv, 444.
37. *Dingler's Polyt. J.*, 1866, clxxx, 403; *Zeit. Ver. Ingen.*, 1866, x, 209.
38. *Dingler's Polyt. J.*, 1870, cxcvi, 101.
39. *Dingler's Polyt. J.*, 1872, ccvi, 85.
40. *Dingler's Polyt. J.*, 1873, ccvii, 338.
41. *Zeit. Ver. Ingen.*, 1868, xii, 373.
42. *Mittheilungen des hannoverschen Gewerbevereins*, 1870, 177; *Dingler's Polyt. J.*, 1871. ccii, 196
43. *Hannoversches Wochenblatt für Handel und Gewerbe*, 1873, 132.
44. *Dampfkessel*, 176.

the possibility of such superheating of the water. Werner[45], Frohning[46], Ludewig[47], Blum[48], Scheffler[49], Jacobi and Fuhst[50], Langen and Stühlen[51], as well as Wittmann[52], on the other hand, maintain that it is entirely possible.

Since, moreover, Burnat[53] and Mayer[54] have actually observed considerable superheating of the water in steam boilers, the possibility of such superheating, especially when the water is oily[55], or is free from air, must be conceded. But whether a good boiler can be destroyed by this agency alone, is entirely questionable. In conjunction with the causes mentioned under 1, 6, and 7, however, such an explosive kind of boiling may become the occasion of an explosion.

Donny[56] proposed to prevent the superheating of the water by blowing a fine stream of air into the boiler. Stiehl's[57] "explodicautor" acts by drawing up a small quantity of the water in the boiler and letting it fall again. Cohn[58] has made some experiments upon the use of electricity for this purpose.

Williams[59] asserts that liquid water always has the temperature of melting ice; the heat apparent in hot water being due entirely to particles of steam distributed through it. He believes, therefore, that if there be too much water in a boiler, an explosion may take place on opening the throttle. How absurd these suppositions are, has already been shown by Meidinger[60].

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45. *Zeit. Ver. Ingen.*, 1863, vii, 77 and 84.
46. *Zeit. Ver. Ingen.*, 1865, ix, 600; 1867, xi, 346.
47. *Zeit. Ver. Ingen.*, 1865, ix, 601.
48. *Zeit. Ver. Ingen.*, 1866, x, 572; *Die Ursachen der Kesselexplosionen.* (Chemnitz; Focke.)
49. *Die Ursachen der Dampfkesselexplosionen.* (Berlin, 1867.)
50. *Zeit. Ver. Ingen.*, 1868, xii, 403.
51. *Zeit. Ver. Ingen.*, 1870, xiv, 341.
52. *Zeit. Ver. Ingen.*, 1873, xvii, 694.
53. *Zeit. Ver. Ingen.*, 1866, x, 345.
54. *Zeit. Ver. Ingen.*, 1868, xii, 146; *Dingler's Polyt. J.*, 1867, clxxxiv, 298.
55. On the injury caused by oily feed-water, see *Dingler's Polyt. J.*, 1857, cxlvi, 221; 1861, clxii, 164; 1864, clxxii, 109; 1865, clxxvii, 430; 1866, clxxx. 254; 1868, clxxxvii, 431; 1869, cxciv, 82.
56. *Dingler's Polyt. J.*, 1847, ciii, 75.
57. *Dingler's Polyt. J.*, 1869, cxci, 181; *Zeit. Ver. Ingen.*, 1868, xii, 697.
58. *Zeit. Ver. Ingen.*, 1870, xiv, 220, 619, 673.
59. *Dingler's Polyt. J.*, 1861, clx, 161.
60. *Dingler's Polyt. J.*, 1861, clxi, 1.

6. *Sudden relief of pressure.* Parkes[61] brings out the important fact, that of 23 boiler explosions investigated by him, 19 took place at the time of starting the machinery; others of these boilers exploded when the safety-valve was opened. The experiments upon boiler explosions which were undertaken under the direction of the Treasury Department of the United States, by a Commission of the Franklin Institute of the State of Pennsylvania[62], have shown that, when an opening is made into a boiler, there takes place at the point where the steam escapes, first a local foaming; and that then this foaming extends itself rapidly over the entire surface of the water in the boiler. This foaming is the more violent, the larger the opening into the boiler. The small experimental boiler used by the Commission, by opening the safety-valve—which was situated at about its center—was so completely filled with foam, that the water was ejected from it with great violence. To the same effect are the remarkable experiments of the Society of Engineers of Breslau[63]. A manufacturer of Bordeaux[64] explains the explosion of the steamboat "Citis" on the supposition that, when the throttle was opened, the hitherto quiet production of steam changed into a tumultuous boiling, the foaming muddy water obstructed the exit passage—the valve being constructed for the escape of steam, not for muddy water—and the boiler could not withstand the increased tension thus produced.

Reiche[65], on the other hand, is of opinion that by the sudden opening of the throttle, by the collapsing of a flue, and the like, a violent foaming takes place so that not only steam but a large quantity of water is discharged also; thus emptying the boiler and lessening the pressure upon it. The boiler explodes according to this theory, from a deficiency of water; but how, is unfortunately not stated.

If the steam-tension in a boiler be suddenly lessened, in consequence either of cooling by the entrance of water[66], of opening the throttle, of collapsing a flue, etc., a violent evolution of steam takes place, by which, under certain conditions, the water of the boiler is hurled with such force against its walls that they cannot resist the blow. This

61. *Dingler's Polyt. J.*, 1842, lxxxiii, 20; *Zeit. Ver. Ingen.*, 1869, xiii, 449; 1873 xvii, 120, 122.
62. *Dingler's Polyt. J.*, 1836, lxi, 324; lxii, 81; 1839, lxxi, 274; lxxiii, 401.
63. *Dingler's Polyt. J.*, 1867, clxxxiv, 74; *Zeit. Ver. Ingen.*, 1865, ix, 689.
64. *Dingler's Polyt. J.*, 1841, lxxx, 313.
65. *Dingler's Polyt. J.*, 1872, cciii, 84; *Zeit. Ver. Ingen*, 1871, xv, 673.
66. *Dingler's Polyt. J.*, 1867, clxxxiv, 75.

theory, first suggested by Colburn[67], is sustained by Bergius, Hofmann[68], Werner[69], and Kurz[70]. Grashof[71], especially, has proved that in consequence of this sudden evolution of steam following the superheating of the water, an actual explosion of the boiler may result. A gradually increasing pressure, as already mentioned, has only the effect of widening little by little, some crack in the most defective part of the boiler; a sudden, explosive increase of pressure, on the other hand, may produce an instantaneous explosion of the boiler at many places at once. The water being suddenly reduced to simple atmospheric pressure, evolves an enormous amount of steam, which, at the instant of its formation, has the pressure corresponding to the temperature of the water from which it was formed; the heat stored up in the water, is transformed into work, and thus causes the destruction. A fracture of the boiler somewhere, may therefore be the occasion of its explosion.

Kayser[72] gives it as his opinion that the masses of steam which become free, almost explosively, as it were, by the sudden relief of pressure, may give so violent a blow on the boiler-walls, that these give way under the strain. While Grothe[73] and Kirchweger[74] call in question the possibility of such a sudden evolution of steam, and Cohn[75] declares that he has observed that no noticeable shock takes place on the sudden relief of pressure, Giesberg[76], Jacobi[77], Heinemann[78], Welkner[79] and others, accept essentially the theory of Kayser.

Ludewig[80] shows that the theory of Dufour in no way conflicts with that of Kayser, but that each supplements rather, the other. While

67. *Dingler's Polyt. J.*, 1867, clxxxiv, 74; *Zeit. Ver. Ingen.*, 1869, xiii, 152.
68. *Dingler's Polyt. J.*, 1867, clxxxvi, 84; *Zeit. Ver. Ingen.*, 1868, xii, 235.
69. *Zeit. Ver. Ingen.*, 1869, xiii, 327.
70. *Zeit. Ver. Ingen.*, 1870, xiv, 341.
71. *Zeit. Ver. Ingen.*, 1867, xi, 762; *Zeitschrift für die gesammten Naturwissenschaften*, 1872, 103.
72. *Zeit. Ver. Ingen.*, 1865, ix, 657; 1866, x, 129, 610; 1867, xi, 147; 1868, xii, 641, 668; 1869, xiii, 449; *Dingl r's Polyt. J.*, 1868, clxxxvii, 518.
73. *Mittheilungen des hannoverschen Gewerbevereins*, 1866, 161.
74. *Mittheilungen des hannoverschen Gewerbevereins*, 1870, 177; *Dingler's Polyt. J.*, 1871, ccii, 196.
75. *Zeit. Ver. Ingen.*, 1870, xiv, 609.
76. *Zeit Ver. Ingen.*, 1866, x, 141.
77. *Zeit. Ver. Ingen.*, 1868, xii, 410.
78. *Zeit. Ver. Ingen.*, 1868, xii, 365, 417.
79. *Heusinger's Organ*, 1871, 67.
80. *Zeit. Ver. Ingen.*, 1866, x, 573.

according to Dufour, the opening of a safety-valve, etc., is only the mediate cause of the explosion, according to Kayser the explosion takes place on opening the valve, directly in consequence of the diminished pressure. To similar purpose are the statements of Hrabak[81] and Schröder[82].

7. *Shocks to the Boiler.* Schafhautl,[83] in his experiments, filled some glass tubes, about five centimeters long, one-fourth with water, sealed them and plunged them into molten zinc whose fusing point is 412° C. They sustained well the enormous pressure of nearly 400 atmospheres, but exploded with great violence when touched with an iron bar vibrating longitudinally. He believes that no explosion is ever caused by excessive tension of steam alone, but that an explosion may take place from a vibratory motion of the boiler-walls; indeed, that such explosions have already happened, caused, for example, from the blow of a hammer, or even from throwing a small stone against the boiler. Similar experiments have been made by Gensoul.[84]

That such a shock is competent, alone, to tear a boiler in pieces, is very doubtful; but, in conjunction with the causes mentioned under 1 and 5, it may have its effect in causing the destruction of a steam-generator.

8. *Overheated Plates.* It is remarkable that, even at the present day, the heat necessary for the work of explosion is so often sought for, not in the water contained in the boiler, but in the overheated boiler-plates. Such an overheating may take place, but can only arise either from want of water, from the formation of incrustations, or from deposits of sediment.

Deficiency of Water. According to Carle and to statements from other sources,[85] if the water sinks below the fire-line, that portion of the fire-surface of the boiler which is no longer wet, becomes red-hot. If now the boiler be fed, or in the case of a ship's boiler, if the ship roll to one side, or if in any other way water comes in contact with the red-hot plates, so much steam is suddenly produced that an explosion is unavoidable.

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81. *Dingler's Polyt. J.* 1867, clxxxiv, 295.
82. *Dingler's Polyt. J.*, 1870, cxcv, 98; *Zeit. Ver. Ingen.*, 1869, xiii, 609.
83. *Dingler's Polyt. J.*, 1842, lxxxiii, 11.
84. *Poggendorff's Annalen*, xviii, 429.
85. *Dingler's Polyt. J.*, 1831, xxxix, 92; 1832, xliii, 242; 1838, lxvii, 81; lxix, 1; 1856, cxli, 14, 152.

Moreover, the experiments of the Commission of the Franklin Institute[86] have shown that by injecting water into a red-hot experimental boiler, a high pressure may be generated in a very short time; but Tassin,[87] on the other hand, reached no other result on pumping water into a red-hot steam-boiler, than to spoil the boiler.

More recent experiments[88] with a red-hot boiler prove that at the injection of the feed-water, the overheated iron strongly contracts, and this causes the boiler to leak around the rivet-holes. The experiments of Fletcher,[89] as well as those made by the Pennsylvania Railroad Company,[90] are to the same effect, and go to show that the explosion of an overheated boiler by the sudden injection of feed-water, is not even possible. Observations similar to these have been made by Oechelhäuser[91] and by Böcking.[92]

The assertion[93] that the steam, superheated by the red-hot boiler plates, is transformed by the water fed into the boiler, into saturated steam of so much higher tension that an explosion results, has already been disproved by the experiments made by the Franklin Institute.[94]

Perkins[95] maintains that, with a low stage of water in the boiler, the steam may become so strongly superheated, that not only the upper portion of the boiler, but even the part situated beneath the water, may become red-hot (?). On opening a valve anywhere, the water takes up this heat, forming instantaneously so much steam that the boiler cannot withstand the pressure. Marestier[96] and Loyer[97] are of the same opinion.

Not more happy is the hypothesis of Sawyer[98] that the level of the water in a steam-boiler changes in consequence of the unequal pressure upon its surface; and that in this way a portion of the boiler-surface is laid bare and overheated, and so gives rise to an explosion.

86. *Dingler's Polyt. J.*, 1836, lxi, 347; 1839, lxxi, 268.
87. *Dingler's Polyt. J.*, 1841, lxxix, 234.
88. *Dingler's Polyt. J*, 1867, clxxxiv, 75; *Zeit. Ver. Ingen.*, 1864, viii, 189.
89. *Dingler's Polyt. J.*, 1867, clxxxiv, 218; *Zeit. Ver. Ingen.*, 1868, xii, 54.
90. *Dingler's Polyt. J.*, 1872, cciv, 354.
91. *Zeit. Ver. Ingen.*, 1868, xii, 667.
92. *Zeit. Ver. Ingen*, 1869, xiii, 544.
93. *Dingler's Polyt. J.*, 1856, cxli, 14.
94. *Dingler's Polyt. J.*, 1850, cxv, 85.
95. *Dingler's Polyt. J.*, 1827, xxiv, 484; xxv, 353; xxvi, 394; 1839, lxxiii, 82, 401.
96. *Dingler's Polyt. J.*, 1829, xxxi, 257.
97. *Dingler's Polyt. J.*, 1839, lxxi, 73.
98. *Dingler's Polyt. J.*, 1850, cxv, 86.

Incrustations and Deposits of Sediment. That boiler-plates which are covered with thick incrustations, may become red-hot, has long been known. Now if these deposits, resting on red-hot plates, be suddenly raised, an explosion may take place, due to the violent evolution of steam.[99] Cousté[100] has even asserted that when we are able to prevent the formation of incrustations in boilers, there will be no more boiler-explosions.

Williams[101] concludes from his experiments that crystalline solid incrustations are less dangerous than porous ones, formed by the solidifying of the sediment, since they conduct the heat far better. Peschka[102] also regards the deposits of sediment as more dangerous than the solid incrustations.

Although it is very doubtful if the steam formed by the rising up of a deposit can alone cause the explosion of a boiler, yet it is quite possible that the plate thus suddenly cooled may become fractured. Moreover, the indirect dangers arising from the fact that red-hot iron has far less strength than that which has not been overheated, and that the plates may burn out and be used up still more quickly than would be the case without a failure of water or the formation of an incrustation, is not to be overlooked.

According to the experiments of the Franklin Institute Commission,[103] an iron plate retains when heated red-hot only one-sixth of its original resistance; yet, theoretically, the tenacity of iron ought to reach its maximum at a temperature higher than the usual temperature of steam. So also, according to Wertheim,[104] many metals, and particularly iron, possess a maximum of elasticity at mean temperatures. Other authorities,[105] on the contrary, state that iron at 300° C., is sixteen per cent. stronger than when cold.

According to Kupfer,[106] the diminution of elasticity for each de-

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99. *Dingler's Polyt. J.*, 1839, lxxi, 283; 1840, lxxvi, 152; 1842, lxxxiii, 20; lxxxvi, 257; 1850, cxv, 15; 1860, clvi, 460; 1872, cciv, 92.
100. *Dingler's Polyt J.*, 1852, cxxv, 260.
101. *Dingler's Polyt. J.*, 1842, lxxxv, 1; *Zeit. Ver. Ingen.*, 1867, xi, 210.
102. *Zeit. Ver. Ingen.*, 1870, xiv, 238.
103. *Dingler's Polyt. J.*, 1839, lxxi, 266.
104. *Poggendorff's Annalen*, 2 Ergänz-Bd, 61.
105. *Dingler's Polyt. J.*, 1850, cxv, 94; *Zeit. Ver. Ingen.*, 1868, xii, 383.
106. *Memoire de l'Academie de St. Petersbourg*, 6, serie vi, 1856, 400.

gree centigrade is expressed, in parts of the whole, as follows:—

For Iron, ...	0·00055
For Copper, ...	0·00082
For Brass, ...	0·00039

Especially noteworthy, however, are the recent investigations of Kohlrausch and Loomis.[107] If the modulus of elasticity at 0° C. be indicated by E^0, then at the temperature τ it is:—

For Iron, .	$E=E^0(1-0{\cdot}000447\tau-0{\cdot}00000012\tau^2)$
For Copper, .	$E=E^0(1-0{\cdot}000520\tau-0{\cdot}00000028\tau^2)$
For Brass, .	$E=E^0(1-0{\cdot}000428\tau-0{\cdot}00000136\tau^2)$

If the definition of modulus of elasticity be referred, not to the unit of length, but to the transverse section, the factors of τ in the case of iron, change to 0·000483, in that of copper to 0·000572, and in that of brass to 0·000485. According to this, the elasticity diminishes by an increase of temperature from 0° to 100° C:—

For Iron, ...	from 4·6 to 5·0 per cent.
For Copper, . . .	from 5·5 to 6·0 per cent.
For Brass, ...	from 5·6 to 6·2 per cent.

The second column of numbers here given refer to the second definition of the modulus of elasticity. Hence the statement that these metals possess a maximum of elasticity at mean temperatures is not correct.

Moreover, the later American experiments on steam-boiler explosions[108] have shown that the power of resistance of a boiler-plate against steam pressure is quite notably diminished by heating it.

Overheating of the boiler-plates, therefore, diminishes still more the still remaining tenacity of the metal. Indeed, according to the experiments of a committee appointed for the purpose,[109] the tenacity of overheated iron amounts to only two-thirds of that originally present. The rivets diminish its strength in like manner, about one-third; so that boiler-iron ought never to be subjected to any greater pressure than one-fifth part of its normal strength. Schafhautl[110] has observed that a boiler which at first worked well under a pressure of twenty atmospheres pressure, after it had been overheated by allowing the

107. *Poggendorff's Annalen*, cxli, 481; *Zeit. Ver. Ingen.*, 1872, xvi, 198.
108. *Dingler's Polyt. J.*, 1874, ccxi, 412.
109. *Dingler's Polyt. J.*, 1850, cxv, 90, 95.
110. *Dingler's Polyt. J.*, 1839, lxxi, 362.

water in it to get low, exploded under a pressure of twelve atmospheres. The overheated iron, too, had become strongly contaminated with sulphur. Indeed, the danger that the iron will take up sulphur from a pyritiferous coal, increases materially at high temperatures.

Ward[111] has made some observations on the temperature of two boilers. He found below the water-line temperatures varying from 131·6° to 135·5°, and in the steam space, from 201° to 260° (evidently in consequence of radiation from the boiler-walls). The water-surface oscillated up and down about fifteen centimeters, so that at some points within the boiler a sudden variation of temperature of 128° took place. That such differences of temperature as this, and consequently also, the strains produced by the various amounts of expansion of the different parts of the boiler, may be materially increased by overheating the plates, needs no formal statement.

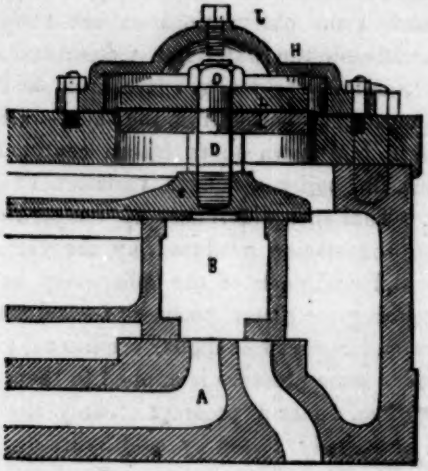
Heated boilers, under otherwise similar conditions, explode far more easily than when the same pressure is applied to them cold. A boiler exploded not long ago, under a pressure of only three atmospheres, which had been previously tested by cold hydraulic pressure, up to nine atmospheres.[112] The cold-pressure test is therefore regarded in many quarters as completely worthless.[113]

In conclusion, if we take into consideration the great loss of fuel occasioned by boiler incrustations—according to Coustè,[114] 40 per cent.—as well as the important fact that muddy and impure water foams strongly, stops up the water-gauges and the manometer, and that the sediment itself is even carried over into the engine,[115] there is ground enough for the opinion that the formation of incrustations and boiler deposits is the worst enemy of steam industry.[116]

111. *Dingler's Polyt. J.*, 1866, clxxix, 240.
112. *Dingler's Polyt. J.*, 1844, xciv, 339.
113. *Dingler's Polyt. J.*, 1872, cciv, 10.
114. *Dingler's Polyt. J*, 1852, cxxv, 260.
115. *Dingler's Polyt. J.*, 1836, lxii, 434; *Zeit. Ver. Ingen.*, 1868, xii, 416.
116. *Dingler's Polyt. J.*, 1874, ccxii, 208.

DESCRIPTION OF A NEW BALANCED SLIDE VALVE.*

By John A. Caldwell, of Pittsburgh.



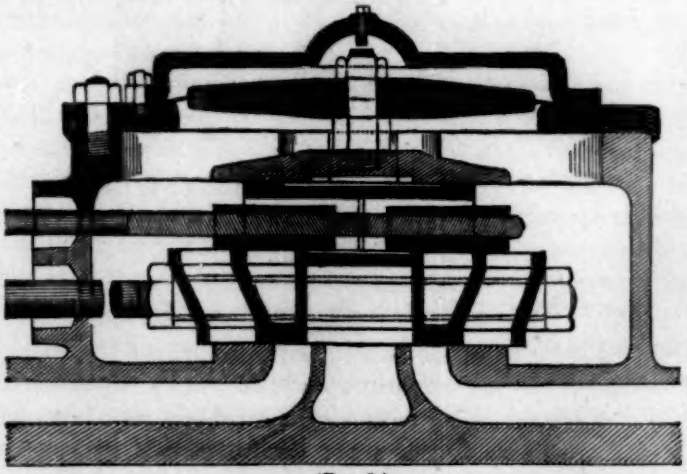
(Fig. 1.)

In Fig. 1, A is the usual valve seat, and B the valve which slides between the seat and the relief plate C. The relief plate is kept from moving in the direction of the travel of the valve by means of arms standing out from its sides and held between jogs cast on the sides of the steam chest, leaving it free to expand from the middle towards each end of the steam chest. The faces between which the valve slides, are rendered flexible or yielding to each other in the following manner: the stem D made of wrought iron is tapped into the relief plate, and on this stem are slipped two circular plates L L of cast iron of sufficient thickness to remain straight under the pressure of the steam; sandwiched between these plates is a copper diaphragm 1-16th of an inch thick, the diameter of which reaches out to the bolts which hold down the bonnet H to the steam chest lid, the plates L L being bound to the stem by the nut O on top. The length of that part of the stem marked D is such that the under side of the copper stands 1-16th of an inch above the top of the steam chest lid. When the bonnet is put on, the edges of the copper are drawn down to the steam chest lid; this not only forms the necessary joint, but also seats the valve properly. The internal area of the bonnet H is made equal to the

* A Paper read at the meeting of the Franklin Institute, held October 21, 1874.

area of the extreme edges of the valve, minus the area required to secure the necessary downward pressure to keep the valve on the seat.

Fig. 1 shows the valve in its simplest form as adapted for an ordinary high pressure, double parted cylinder. On these engines a small hole is drilled in any part of the bonnet to admit the atmosphere, and ascertain when any leakage is going on. For condensing engines where the pressure at B and A falls below the atmosphere, a small pipe is led from the exhaust at A to the interior of the bonnet H. The same arrangement is used on locomotives, also, where the pressure rises considerably at B and A owing to the choking of the exhaust by the action of the link motion. If the valve is to be made to rest lighter on the seat, the bonnet H is removed, and its interior diameter enlarged. If the valve requires to be planed, the depth of the cut is made up by inserting a copper washer between the lower plate L and shoulder D. The coppers have worked four years without renewing. Cylinders above 30 inches diameter have two stems D, with 1 bonnet; cylinders from 45 upward, have four bonnets and four stems, one on each corner of steam chest. In case of water in the cylinder and the valve jerking off its seat, the copper yields 1-16th of an inch without injury. A bolt J keeps it from rising more than that. The bolt J is cut the right length, and is screwed down to the head to prevent its being tampered with.

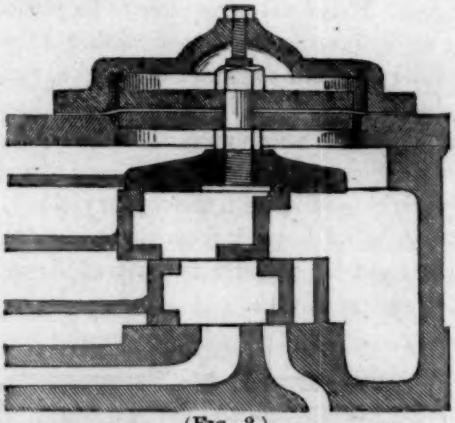


(Fig. 2.)

Figs. 2 and 3 show its adaptation as a cut off valve. The former has plates on the back of the main valve which are moved to and

from each other by means of a right and left hand screw operated by a hand wheel on the eccentric rod while the engine is in motion, thereby producing variable cut off. The latter has one valve on the back of the other and set permanent, and is operated by one eccentric, or made variable by two eccentrics, with link motion or otherwise. In this case the two valves are nearly balanced, and with the plates on back of the valve, the surface in contact will prove downward pressure. The cavity in the main valve over which the plates are shown in Fig. 2 is open at the ends and consequently that part of the plate passing over it is balanced.

The slide valve here described was patented by James Hemphill, of Pittsburgh, May 26, 1868.



(FIG. 3.)

[Entered according to act of Congress, in the year 1873, by John Richards, in the office of the Librarian of Congress at Washington.]

THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

BY J. RICHARDS, Mechanical Engineer.

[Continued from Vol. lxviii, page 275.]

TURNING LATHES.

In machinery the ruling form is cylindrical sections; in structures other than machinery that does not involve motion, the ruling form is rectangular.

Motion in machinery is mainly rotary; and as rotary motion is accomplished by cylindrical parts such as shafts, bearings, pulleys

and wheels, we find that the greater share of machine tools are directed to preparing cylindrical forms.

If the apprentice will note the amount of turned, bored and drilled surface in ordinary machinery, compared to the amount of planed surface in the same machinery, he will find the former not less than as two to one in the better class of machinery, and as three to one in the coarser class of work; from this he can see approximately the proportion of tools needed for operating on cylindrical surfaces and on plane surfaces, which, assuming that the cutting tools had the same capacity in the two cases, would be in the ratio of three to one.

In practice, the truth of the proposition is fully demonstrated by the excess in the number of lathes and boring tools over those for planing.

The Engine Lathe is for many reasons called the master tool in machine fitting. It is not only the leading tool so far as performing the greater share of the work, but the engine lathe as an organized machine combines perhaps a greater number of useful and important functions than any other machine that has ever been devised.

A lathe may be used to turn, bore, drill, mill, or cut screws, and with a strong screw feed, may be employed for planing of some kinds. But what is still more strange, notwithstanding these various functions, a lathe is a comparatively simple machine without complication or perishable parts, and requires no special change in adapting it from one purpose to another.

For milling, drilling and boring ordinary work within its range, a lathe is by no means a make-shift tool, but performs these various operations with nearly all the advantages of machines adapted to these different processes.

An ingenious workman who understands the adaptation of a modern engine lathe of American manufacture, can build almost any kind of light machinery without other tools, except for planing, and may even perform the planing when the surfaces are not too large; and what is still stranger he can in this way build machinery at a cost almost as small as though he had a full equipment of tools to use.

The lathe as a tool for producing heliacal forms would occupy a prominent place among machine tools even were it capable of no other work; the number of parts in machinery that have screw threads is astonishing when we consider them; clamping-bolts to hold parts

together constitute alone a large share of the fitting in machines of all kinds, while screws are the most common means for increasing power and performing adjustments.

A Finisher's engine lathe consists essentially of a strong inflexible shear or frame, a running spindle with from eight to sixteen changes of motion, a sliding head, or tail stock with a dead centre, and a sliding carriage to hold and move the tools arranged to traverse on the shear by positive connection with the spindle.

For a half century past no great change has been made in engine lathes, at least no new principle of operation has been added, much improvement has been made in their adaptation and capacity, especially in adding to the convenience of operating upon various kinds of work.

During late years, improvements have been made in the facilities for changing wheels in screw cutting and feeding, in the use of frictional starting gear for the carriages, independent feed movement for turning, arrangements to adjust the tools, and for cross feeding and so on, adding no doubt greatly to the efficiency of lathes, but mainly supplanting the skill of lathemen.

A proof of this last proposition is found in the fact that a good turner will perform nearly as much work and do it as well on an old English lathe, with a plain screw feed, as can be performed on the more complicated lathes of modern construction; but as economy of skill is sometimes an equal or greater object than economy of manual labor, an estimate as to tool capacity should be made accordingly.

The vital points in a lathe or such as many most readily affect its performance, are first—truth in the bearings of the running spindle which communicates a duplicate of its shape to the pieces that are turned,—second, coincidence between the line of the spindle and the movement of the carriage,—third, a cross feed of the tool at a perfect right angle to the spindle or to the carriage movement,—fourth, durability in bearing surfaces, especially in the spindle bearings and sliding track. To these may be added many other points such as the truth of the feeding screw, rigidity of the frame, and so on; but these requirements are obvious.

To avoid imperfection in the bearings of the running spindle of lathes, or any lateral movement that might exist in the running bearing there have been many attempts to construct lathes with a dead centre at both ends for the more accurate kinds of work, an arrange-

ment that would produce a true cylindrical rotation of the piece, but at the same time involve mechanical complications and difficulties that outweigh the object sought; besides it has been proved in practice that good fitting, and good material in the bearings and spindles, insures all the accuracy that ordinary work demands.

The apprentice will notice that in some lathes the carriages move on what is termed V tracks that project above the top of the lathe frame, and that in other lathes the carriages slide on top of the frame with a flat bearing. As these two plans of mounting lathe carriages have led to considerable discussion on the part of different makers and as its consideration may suggest a plan of analyzing other questions of a similar nature, I will notice some of the conditions that must be considered in the two cases, calling them by the names of flat shears and track shears.

These two plans of track shears and flat shears must be considered first in reference to the effect produced upon the carriage action, such as endurance of wear, rigidity of the tools, convenience of operating and the cost of construction.

The cutting point in both turning and boring on a lathe is at the side of the piece or the hole, and any movement of the carriage horizontally across the lathe shear effects the motion of the tool directly and to the extent of such movement, so that parallel turning and boring depend mainly upon avoiding any cross movement or side play of a carriage on the lathe shear. The movement of the carriage parallel to the line of the spindle and the work is best maintained by wearing surfaces at a right angle to this horizontal movement or by surfaces normal to the shear tops, or to state it in less words the parallel movement of lathe carriages in a vertical plane is dependent upon vertical bearing surfaces. In this respect there is not much difference between the flat shear and track shear, except in the angle of the bearing surfaces which will be noticed further on.

A true movement of the carriage in a vertical plane is especially important in boring with a bar, but in the case of using fixed tools as in turning, and in chuck boring, deviation of the carriage in a vertical plane is of but trifling importance compared to deviation in a horizontal plane.

To prevent deviation of lathe carriages horizontally, or across the shear the two planes of the flat shear and the track shear are not much different as a rule in the extent of wearing surface, but with a flat

shear the stress upon the carriage falls upon but one side of the shear, while with V guides it falls on both sides.

The strain in turning, or the thrust of the cut as it may be termed, falls on a carriage usually at an angle of about thirty degrees from the spindle downward toward the front of the lathe; this strain is very great, and is of course best opposed by bearing surfaces at a right angle to the line of the force, and so arranged as to employ the whole strength of the shear to resist it. Neither of these conditions is filled by the flat shear, as this cutting strain falls mainly on the gib at the back of the lathe, and at an acute angle with the bearing surfaces; this strain also falls only on one side of the shear, and unless there are a great number of cross girts, has but one-half its strength to withstand the thrust of the tool.

With a track shear that has double ways, both sides of the shear equally resist the tool thrust or cutting strain, and the bearing surfaces stand at, or nearly at, a right angle to the line of the force.

A carriage moving on V tracks always moves steadily and can have no play in any direction until lifted from its bearing, and the lifting is easily opposed by adjustable gibs; while a carriage on a flat shear is apt to have play on the shear in a horizontal direction because of the freedom that it must have to secure easy movement. In the case of the tracks it may also be mentioned that the weight of the carriage acts as a constant force to hold it steady, while with the flat shear the weight of the carriage is in a sense opposed to the gibs, and has no useful effect in steadying or guiding it.

The rigidity and steadiness of the tool is notoriously in favor of the triangular tracks, so much so that nearly all American manufacturers construct their lathes in this manner, although it adds no inconsiderable cost in fitting.

It may also be mentioned that the track shears usually have a triangular way for the moving head as well as for the carriage, which leads to the advantage of firmly binding the shear together in fastening the moving head, which in effect becomes a strong girt across the frame at the end of the work.

The reader will, in following this matter thus far, see how many conditions may have to be considered in reasoning about so apparently simple a matter as the form of ways for lathe carriages, and may even go on to many more points that have not been mentioned; it shows how abstruse a matter it is to reason about mechanical problems even when the premises are all at hand and seemingly clear.

The lathes in common use for machine fitting are screw cutting engine lathes, lathes for turning only, double geared, single geared, and back geared lathes, lathes for boring, hand lathes, and pulley turning lathes; also compound lathes with double heads and two tool carriages. These are common modifications which the apprentice can soon familiarize himself with by remembering this classification, or assuming one of his own.

These various lathes, although of a widely varied construction and adapted to uses more or less dissimilar, are still the engine lathe, either with some of its functions omitted to simplify and adapt it to some special work, or with some of the operative parts compounded to attain more capacity.

In respect to lathe manipulation, which is perhaps the most difficult to learn of all shop operations, I will give the following hints that may prove of service to the learner:

At the beginning, study the form of tools; this is one of the great points in lathe work; the greatest distinction between a thorough and indifferent latheman is that the first knows the proper form and temper of tools and the latter does not. The adjustment and presenting of tools is soon learned by experience, but the proper form of tools is not soon learned. One of the first things to study is cutting angles, both as to clearance below the edge of the tool, and the angle of the edge itself with reference to turning, and also for boring, which is different from turning. The angle of lathe tools is clearly suggested by diagrams, and there is no better first lesson in drawing than to construct diagrams for cutting angles on plane and cylindrical surfaces.

A set of lathe tools should consist of all that are required for every variety of work that comes to the lathe, so that no time is lost in waiting to prepare tools after they are needed. An ordinary twenty inch engine lathe operating on ordinary work will require from twenty-five to thirty-five tools, which will serve for every purpose if they are kept in order and kept in place. A workman may get along with ten tools or even less, but not to his own satisfaction, nor in a speedy way. Each tool should be properly tempered and ground, ready for use "when put away;" if a tool is broken, it should at once be repaired, no matter when it is likely to be used. A workman who has pride in his tools, will always be supplied with as many as he needs, because it takes no computation to tell that fifty pounds of extra cast

steel tools as an investment, is but a small matter compared to a little gain in manipulation by having the tools at hand.

To an experienced mechanic a single glance at the tools on a lathe is a sufficient clue to the skill of the workman who operates the lathe; if the tools are ground ready to use, of the proper shape, and placed in order so as to be reached without delay, the user is at once to be set down as having two of the main qualifications of a first class workman, which are order, and a knowledge of tools; while on the contrary, a lathe board piled full of old waste, clamp bolts, and broken tools, shows a want of system and order, without which no amount of hand skill will make a workman.

It is also necessary to learn as soon as possible the technicalities pertaining to lathe work, and still more important to learn the conventional modes of performing the various operations. Although lathe work includes a large range of operations that are continually varied, yet there are certain plans of performing each that has by long custom become conventional; to gain an acquaintance with these the apprentice should watch the practice of the best workmen and follow their plans as near as he can, not risking any innovation or change until it has been most carefully considered. Any attempt to introduce new plans or modes of chucking work, setting and grinding tools, or other of the ordinary operations in turning may not only lead to awkward mistakes, but will at once put a stop to useful information that must be gained from others.

The technical terms used in lathe work are soon learned, generally sooner than they are needed, and often misapplied, which is worse than to be ignorant of them.

In cutting screws never refer to that mistaken convenience called a gear list, that is usually stamped on some part of engine lathes. The screw to be cut is to the lead screw on the lathe as the wheel on the screw is to the wheel on the spindle, and every workman should be familiar with so simple a matter as computing wheels for screw cutting, when there is but one train of wheels. Wheels for screw cutting are computed not only nearly as soon as read from an index, but the advantage of being familiar with wheel changes is very important in other cases, and frequently such combinations have to be made when there is no index at hand.

The following matters may be computed and studied with advantage in operating a lathe: the rate of cutting movement on iron, steel, and

brass, the relative speed of the belt cones, whether the changes are by a true ascending scale from the slowest, the rate of feed at different changes estimated like the threads of a screw at so many cuts per inch, the proportions of cone or step pulleys to insure a uniform belt tension, (referring to the lathe and countershaft in use as an example) the theory of the following rest as used for turning flexible pieces, the difference between three and four bearing points in centre and following rests, the best means of testing the truth of the lathe. All these matters and many more are subjects not only of interest but of use in learning lathe manipulation, and their study will lead to a logical method of dealing with other questions that will arise continually in the fitting shop.

Learn to use hand tools by employing them on every possible occasion. A great many of the modern improvements in engine lathes are only to evade hand tool work, and in scarcely any case effect any saving except in skill. A latheman who is skillful with hand tools will on many kinds of light work perform more and do it better on a hand lathe than on an engine lathe, while there is always more or less that can be performed to advantage with hand tools even on the most elaborate engine lathes.

A Lancashire latheman, in a test that was made at Manchester, England, a few years since, in facing the hubs of wrought iron railway car wheels, exceeded the performance of the best slide lathes with his hand tools, both as to smoothness of the work and in the time required to perform it. It is no uncommon thing for one of these old hand tool lathemen to lock his slide rest and resort to hand tools on many kinds of work when he is in a hurry.

Planing or Reciprocating Machines.

The term planing should properly be applied only to machines that produce planes or flat surfaces, but the technical use of the term makes it include all cutting that is done in right lines, or by what may be called straight line movement of the tools.

As no motion can be continuous except rotary motion, and as rotary movement is almost exclusively confined to shaping cylindrical or circular pieces, the proper distinction between machine tools that operate in straight lines and those that operate with circular movement will be to call them rotary and reciprocating.

The apprentice will notice that all machines except milling machines that act in straight lines and produce plane surfaces have

a reciprocating movement. This class includes planing, slotting and shaping machines, which, with lathes, makes up the greater share of finishing tools.

It is strange, considering the simplicity of construction and the very important office filled by machines for cutting on plane surfaces, that they were not sooner developed and applied in metal work; many men yet working at the trade can remember when all flat surfaces were chipped and filed, and long after engine lathes had reached a state of efficiency, planing machines were not known. This is no doubt to be accounted for in the fact that graduated and reciprocal motion, except that produced by cranks or eccentrics, was unknown or regarded as impracticable for such purposes until late years, and when finally applied it was thought impracticable to have such movements operate automatically. This may seem quite absurd to even the apprentice of the present time, yet the matter, as a mechanical problem, is by no means as simple as it may at first thought appear.

A planing machine platen for instance, moves at a uniform rate of speed each way, and by its own motion shifts or reverses the driving power at each extreme of the stroke; presuming that there were no examples to be examined, the apprentice will find many easier problems than to tell how a planer platen can shift its own belts. If the platen or table disengages the power that is moving it, the platen stops; if the momentum carries it enough farther to engage or connect other mechanism to drive the platen in the opposite direction, the moment such mechanism comes into gear the platen must stop and no movement can take place to engage clutches or shift belts. This is a curious problem that will be referred to again farther on.

Reciprocating tools are divided into those wherein the cutting movement is given to the tools, as in shaping and slotting machines, and machines wherein the cutting movement is given to the material to be planed, as in the common planing machine, and very strangely we find in general practice that tools for both the heaviest and the lightest class of work, such as shaping and cutting planers, operate upon the first principles, while work of a medium class is mainly performed on the second kind.

This problem of whether to move the material or to move the tools for the cutting motion, in planing, is an old one, and both opinion and practice yet vary to some extent, but machinists seem now to have settled down upon tolerably constant rules.

Judging upon theoretical grounds, and leaving out the mechanical conditions of operation, it would at once be concluded that the proper plan is to move the lightest body; that is, if the tools and their attachments are heavier than the material, then the material should be moved for the cutting action, and vice versa; but in practice there are other conditions to be considered that are more important than the question of relative weight in the reciprocating parts, and it must be remembered that in solving any problem pertaining to machinery the conditions of operation are to be considered first and have precedence over questions of strain, arrangement, or the general principles of construction. A standard planing machine, such as is used for most kinds of work, is arranged with a running platen or carriage upon which the material is fastened and traversed beneath the cutting tools. The uniformity of arrangement and design in machines of this kind throughout the world wherever they are used must lead to the conclusion that there are substantial reasons for this arrangement instead of having a cutting movement of the tools.

A planing machine with a running platen occupies nearly twice as much floor space, and requires a frame at least one third longer than if the platen was fixed and the tools performed the cutting movement. The weight, also, that has to be traversed, including the carriage, will in nearly all cases exceed what it would be with a tool movement; so that there must exist some very strong reasons in favor of the moving platen, which I will now attempt to explain, or at least to point out some of the more prominent that have no doubt led to the common arrangement of planing machines.

First it must be remembered that strains caused by the cutting action, in planing or other machines, fall within and are resisted by the framing, even when the tools are supported by one frame and the material by another. Such frames have to be connected by means of foundations, which are to be regarded as a constituent part of the framing in such cases. Direct action and reaction must be equal; if a force is exerted in any direction there must be an equal force acting in the opposite direction, so that every machine must absorb its own strains.

Keeping this in view and referring to an ordinary planing machine which the reader is presumed to be familiar with, I will assume the focal point of the cutting strain in a planing machine to be at the point of cutting and to radiate from this point as from a centre, and

start from this cutting point and follow back through the mechanism to the frame proper; first starting with the tool and its supports, and secondly, from the material to be planed to the framing again, to examine what may be called the attachments.

Beginning at the tool there is first a clamped point between the tool and the swing block; second, a movable pivoted joint between the block and shoe piece; third, a clamped joint between the shoe piece and the front saddle; fourth, a moving joint where the front saddle is gibed to the swing plate or quadrant plate; fifth, a clamp joint between the quadrant plate and the main saddle; sixth, a moving joint between the main saddle.and the cross head; seventh, a clamp joint between the cross head and standards; and eighth, bolted joints between the standards and the main frame; making in all eight distinct joints between the tool and the frame proper, three of which are moving joints and four clamped joints depending on friction alone, and one bolted joint.

Starting again from the cutting point, and going the other way from the tool to the frame, there is first a clamped and stayed joint between the material and platen, next a running joint between the platen and frame, and this is all; one joint that is firm beyond any chance of movement, and a moving joint that is not held by adjustable gibs, but by gravity, a force that acts equally at all times and is the most reliable known in mechanics.

Reviewing these mechanical conditions, the apprentice may at once see a sufficient reason for the platen movement of planing machines, and that it would be objectionable if not practically impossible to add the traversing or cutting action to the tool, that is already supported through the medium of eight joints, and to traverse for cutting would require a moving gib joint in place of the bolted one named last in the list.

This is not, however, the only reason that has led to the running platen for planing machines, although the most important one.

If the cutting movement was performed by the tool supports, it would necessarily follow that the larger the piece to be planed, and the greater the distance from the platen to the cutting point, the farther the tool must be from its supports; a reversal of the conditions required, because the heavier the work the greater the cutting strain will be, and the tool supports less able to withstand the strain.

It might be argued that the same conditions apply to the standards of a common planing machine, but the case is different; the upright framing is easily made strong enough by increasing its depth; but the strain upon a running joint is as the length of the bearing surfaces are to the distance at which a force is applied, when the force acts parallel to the bearing faces. With a moving platen the larger and heavier the piece to be planed the more firmly the platen is held down, and as the cross section of the pieces is presumed to increase with their depth, the result is that a planing machine that is properly constructed will act nearly as well on deep as on shallow pieces.

The lifting action on the platen at the front end is of course increased as the height at which the cutting is done above its top, upon the principle just stated; but this has not been found a difficulty of any importance in practice and has not even required extra length or weight in the platen, beyond what is demanded to receive the work and to resist flexion in fastening heavy work.

The reversing movement of the platen already alluded to is one of the most complex problems that exists in machine tools.

The platens as a rule run back at twice the forward or cutting movement, and as this is uniform throughout each motion and requires to be stopped at the extremes by meeting some elastic or yielding resistance, that, to use a steam phrase, "cushions" or absorbs the momentum, and starts the platen back for the return stroke.

This object is attained in planing machines by the friction of the belts, which not only cushions the platen like a spring, but in being shifted oppose a gradually increasing resistance until the momentum of the platen is overcome and its motion reversed. By multiplying the movement of the platen with levers or other mechanism, and by reason of the movement that is attained by momentum after the driving power ceases to act, it is found practicable to have a platen "shift its own belts," a result that would never have been reached by theoretical deductions, and was no doubt discovered by experiment, like the automatic movement of engine valves.

It is not intended to claim that this platen-reversing motion can not, like any other mechanical movement, be resolved by mathematical principles, but that the mechanical conditions are so obscure and the invention made at a time that warrants the supposition of accidental discovery. In fact the accomplished fact is barely a mechanical possibility as planing machines are now constructed. In the driving

gearing of planing machines the conditions that most favor the reversing movement are high speed and narrow driving belts.

The time in which a belt may be shifted is as the speed and width of the belt; a belt to be shifted must be deflected or bent edgewise, and from this cause wind spirally in order to pass from one pulley to another. To bend or deflect a belt edgewise there will be required a force inversely as the width of the belt, and that when the belt is deflected by the shifters the time of passing from one pulley to another is as the number of revolutions made by the pulleys.

Planing machines of the most improved construction are driven by two belts instead of one, and many mechanical expedients have been adopted to move the belts differentially, so that both should not be on the driving pulley at the same time, but move one belt before the other in alternate order; an object that is easily attained by simply arranging the two belts with the distance between them equal to one and one-half or one and three-fourths times the width of the driving pulley; the effect is the same as that accomplished by differential shifting gear, with the advantage of admitting of adjustment as to the action of the two belts.

Another principle in planing machines that deserves notice is the manner of driving the platen, which is usually by means of spur wheels and a rack on its underside. The rack movement is smooth enough, and effective enough so far as a mechanical connection between the wheels and platen, but there is a serious difficulty to be met with in the torsion and elasticity of cross-shafts and a train of reducing gearing. In all other machines for metal cutting there is a studied object in having the supports for both the tools and the material as rigid as possible, but in the common type of planing machines, such as have rack and pinion movement, there is a controversion of this principle inasmuch as a train of wheels and several cross shafts constitute a very effective spring between the driving power and the point of cutting; a matter that is at once proved by planing across the teeth of a rack or the threads of a screw on a machine that is arranged with spur wheels and the ordinary reducing gearing. It is true the inertia of the platen is interposed and in a degree overcomes this elasticity, but in no degree that amounts to a remedy.

The planing machines invented by Mr. William Sellers and manufactured in America and in England, are free from this elastic action of the platen, which is moved by a screw pinion set on a shaft with its axis diagonal to the line of the platen movement, so that the teeth or

threads of the pinion act partly by a sliding contact and partly by a progressive forward movement like the teeth of wheels. The rack on the platen is arranged with its teeth at a proper angle to balance the friction arising from the rubbing action of the pinion, which angle has been demonstrated as correct at 5°, the standard co-efficient of friction.

As the pinion-shaft is strongly supported at each side of the pinion and the thrust of the cutting force falling mainly in the line of the pinion shaft, there is but little if any elasticity in the gearing and the motion is positive and smooth.

This gearing has been described here mainly for the purpose of calling attention to what constitutes a new and singular mechanical movement, one that will furnish a most interesting study and one that deserves a more extended application in producing slow reciprocating movements. The drawings of the English patent office will furnish data and proportions for planing machine gearing of this kind.

(To be continued.)

Economy of Fuel in Furnaces.—M. Foucault, in a report to the Industrial Society of Rheims, combats the idea that the smokelessness of a fire can effect a notable saving in the amount of fuel burnt. He alleges also, on the other hand, that a considerable loss of economy is produced by smoke-consuming apparatus. He brings, in support of his opinion the long series of observations made by the Industrial Society of Mulhouse, which have proved that, with the ordinary boiler furnaces, it is only necessary to consume from 125 to 150 cubic feet of air for each pound of coal, while furnaces, for the most part, pass twice that quantity. If the draught be reduced in quantity much smoke is evolved, but the products of combustion, circulating more slowly, part with their heat more readily to the boiler flues. It is further proved that the best means of reducing the loss of heat by the chimney is by the use of feed heaters in the flue, so as finally to reduce to 200° the products of combustion which are often discharged as hot as 400°. Feed-water heaters well set, will produce an economy of from 11 to 20 per cent., with a reduced draught. The conclusion is that furnaces with large area and suitable feed-heaters are the most economical in all respects. But in order to obtain the best results much care is needed in stoking. A little at a time and often, should the coal be spread over the front of the fire, and the bright coal pushed back to the bridge. At the same time the least possible quantity of cold air should be admitted.

Chemistry, Physics, Technology, etc.

THE REAL REASONS WHY CASTINGS IN IRON ARE ACCURATE COPIES OF THE MOULD.

By Robert Mallet, C.E., F.R.S.*

The fact that cast iron does take very accurately the form of the mould in which it is cast has been for a length of time attributed to the supposed fact that the metal expands in volume while passing from the liquid to the solid state—a supposition which for more than a century has passed current, though without any sufficient proof. In a paper read before the Royal Society on the 11th of June last, an abstract of which, taken from the "Proceedings" of that society, has appeared in *The Engineer* for the 3d July last, I have disproved by two independent experimental methods the supposed fact that cast iron does expand in consolidation from fusion. The paper itself will probably be published in full by the Royal Society in the latter part of this year. Meanwhile it may be stated that the methods pursued consisted in, first, the determination of the specific gravity of liquid cast iron, by weighing equal volumes of the liquid metal and of distilled water, the specific gravity of the same cast iron at 60° Fahr. being also determined; secondly by determining the dimensions of a spherical shell of cast iron heated to bright redness, and then filled with liquid cast iron before being heated, when filled, and during the cooling back to the temperature of the atmosphere, when its dimensions were found the same as at the beginning; also by determining the specific gravities of the circumferential and central portions of the ball of cast iron when cold which had filled the shell. The central portions were found much less dense than the circumferential parts, as is well known to be the case in all castings in iron, of whatever size and form; but if the expansion in volume had taken place in the ball cooling by radiation, the central portions must have been found much more dense than the circumferential parts. The agreement of these two independent trains of experiment removes all doubt as to the completeness of the proof that cast iron does *not* expand in volume in passing from the state of liquid fusion to that of solidity by cooling; and it is therefore certain that the degree of exactness with

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which cast iron takes the form of the mould into which it is cast is to be otherwise accounted for. It is not necessary I should here advert to the objects in relation to certain lunar volcanic theories with which the above experiments were undertaken, nor to the conditions under which cast iron in the solid state may or may not float on cast iron in fusion; the latter facts, erroneously interpreted, having been, in fact, the foundation upon which the supposed notion of the expansion of cast iron during consolidation has been based. For these and the details of the experiments I must refer to the paper itself. In the meantime some useful deductions of a practical character may be drawn from the facts ascertained. Were it the fact that cast iron in solidifying *did* expand in volume, a little consideration will show that such expansion would result, not in the casting being an accurate copy of the mould—whether of green or dry sand, or loam—but must be a distorted copy, the expansion in volume of the metal filling the mould being, in effect, the same as if it were exposed to the hydrostatic pressure of a liquid pumped into it, the yielding to which would be greatest where the walls were least resistant, or where the force to which they are exposed is greatest—namely, where the surfaces exposed to pressure were the largest. Thus, for example, a flat plate moulded from a pattern of equal thickness throughout would when cast, be no longer of equal thickness throughout, but have one or both of its broad surfaces forced outwards so as to make the plate thickest towards the central parts, whilst the edges and corners of the plate which consolidate first would remain nearly unaltered, and the metal be found not even completely forced into contact with those parts of the mould; in fact, no form of casting except that of a sphere could under the supposed conditions of expansion in volume remain an undistorted ectype of the pattern, nor could any rigidity in the mould prevent this, the expansive force being by hypothesis irresistible, like that of water freezing into ice.

Cast iron does, however, as is well known, take the form of the mould, as formed of sand or loam by the usual methods of the founders, with great fidelity. We must except, however, the case of chills or massive moulds of cast iron, the liquid metal cast into which is so instantly chilled by contact as not to form a very accurate transcript of the mould. But though cast iron does take a very sharp and accurate transcript of the mould when cast, it does not do so to a greater extent than do several metals to which the supposed property

of expanding or consolidation has never been attributed. Thus zinc affords castings of exquisite sharpness from sand moulds, as all those must have remarked who have seen the superb ornamental castings in that metal for architectural and other purposes which form the staple trade of the great German and Belgian zinc foundries. Lead also, when carefully preserved while in fusion free from oxidation and cast in slightly greased moulds so as to reduce any oxide formed therein, affords castings of exquisite sharpness, as may be observed in those of the ancient lead work of the roofs of churches and other buildings of from 200 to 300 years ago in France and Belgium. Gold, silver, copper, and most of their alloys, on the contrary, afford generally more defective castings and wanting in sharpness. The circumstances upon which these opposite results arise are extremely complicated, and to fully elucidate them would require more space than can be here afforded; they involve conditions mechanical, chemical, and molecular, affecting both the metal cast and the nature of the mould in which it is cast, as well as the relations of these to each other. Amongst these the following are, perhaps, the most important: First, the density of the metal itself. Whatever be the nature of the metal, it fills the mould when full under a certain hydrostatic pressure due to the height of the liquid column and to the density of the metal, and whatever the metal may be, this is the mechanical force by which it is compelled to follow and fill while liquid the sinuosities of the mould. Let us suppose the liquid head constant, say 2½ feet or 30 inches, we readily see how enormous a difference there yet is in the mould-filling force due to density alone in the five metals, aluminum (which gives extremely defective castings), zinc, cast iron, lead, and gold, their densities being:—

	Specific gravity.	Lbs. per sq. inch under 30-in. head.
Aluminum,	2·560	2·820
Cast iron,	7·110	7·856
Zinc,	7·146	7·896
Lead,	11·360	12·552
Gold,	19·340	21·371

Thus, in the last of these metals the hydrostatic pressure tending to fill the mould completely is about seven and a-half times greater than in the case of aluminum, and yet both these metals produce inferior castings, while the three intermediate metals afford sharp and good ones. Secondly, the specific capillarity when in fusion, and

viscosity while passing from the liquid to the solid state. Different metals are liquid in very different degrees while in perfect fusion, and therefore require very different degrees of pressure to force them into angular cavities. Upon this point physicists have as yet given us but little exact information. The greatest diameter of spherical drops capable of being assumed by any metal when taken in connection with its density is, however, a rough measure of the resistance which each presents to being forced into angular cavities of a mould of such material that it is not wetted by the liquid metal; thus fluid solder will readily penetrate between the edges of two clean tin plates, but will not enter at all if the plates be tarnished or blackened by a candle flame. Drops of mercury cohere at larger diameters than those of liquid lead. So also different metals differ in the range of viscosity through which they pass between their state of most perfect liquidity and that of solidity. Lead and some of its alloys, such as plumbers' solder, pass through a very long range of viscosity; brass and copper do so likewise, though in less degree; cast iron, and in general all the metals that crystallize most readily and best, pass through a very brief stage of viscosity. Where the melting point of the metal is a low one, one of the effects of this prolonged viscous stage, during which the metal contracts by loss of heat, is that its withdrawal from the sides of the mould is not compensated by a sufficient continuance of hydrostatic pressure, owing to imperfect liquidity. Cast iron is remarkably free from this objection; its melting point being very high and its range of viscosity small and confined to a small range of temperature, the metal is maintained, though constantly contracting by loss of temperature, in close contact with the mould by hydrostatic pressure up to within a brief period of its setting. Thirdly, upon the tendency of the metal to oxidate or combine with other elements presented to it in casting, and producing compounds less fusible than the metal itself, greatly depends the perfection or imperfection of the castings produced from it. Fluid zinc oxidates but very slowly up to a temperature somewhat above its melting point, but it oxidates rapidly at and above a bright red heat; hence zinc gives perfect castings; but when it is alloyed with copper the melting point of the brass is raised to such a point that the zinc oxidates very rapidly, and produces that "tailing" and general scurfiness of surface which is the plague of the brass founder, and the oxide of zinc is not

reducible back to metal at the temperature at which brass is cast by any chemical agent capable of being introduced into the substance of the mould. In cast iron, on the other hand, its tendency to oxidate by contact with the atmosphere when in fusion is opposed by the presence of silicon and carbon in the metal itself, and any oxide superficially formed is reduced back to metal with great facility by the hydrogen and carbonic oxide evolved from the moisture and charcoal, or coaldust, or other carbonaceous matter entering into the constituents of the mould. Gold is inoxidizable, but possesses a vigorous affinity for sulphur, and it is probable that the film which may be observed upon the surface of molten gold in casting, and which produces "tailiness" in the ingot or bar, consists of some sulphur compound taken up from the gases from the fuel employed for fusing it. Copper also casts badly, as when in fusion it is constantly either taking up carbon or oxygen as the heat of the furnace is either a reducing or an oxidating one, and the great cleanness of castings produced from phosphorized copper arises from the presence of the small amount of that element precluding it from taking up carbon, on the one hand, and shielding it from oxidation on the other. Fourthly, a high melting point and a high specific heat are favorable to the production of perfect castings, as prolonging the time during which *cæteris paribus* the metal filling the mould is subjected to its own hydrostatic pressure, thus more completely forcing it into sinuosities and expelling air bubbles or other gaseous matters. If the fusing point be very low, as in the case of lead or tin, the viscous point is so rapidly reached by the loss to the mould of the small amount of heat present in the metal that there is but little chance of air bubbles or particles of unreduced oxide being previously forced out. Fifth, the absolute amount of contraction of any metal between the temperature at which it is poured and that of the atmosphere, forms also an element in the perfect correspondence of the casting to the form of the mould in which it was cast. On comparing this rough sketch of some of the principal conditions upon which the degree of perfection of castings in various metals depends, it will be obvious that amongst all the metals commonly used for castings in the arts, cast iron occupies an extremely favorable position: its density is sufficient to press it when liquid effectively into the mould, its capillarity is not very great, its range of viscosity is small, and it

possesses the paramount advantage that whatever oxide may be formed in the casting processes is precluded from becoming diffused throughout the mass by the silicon and carbon present, and that any oxide formed on the surfaces in contact with the mould is instantly again reduced by the hydrogen and carbonic oxide evolved from the mould itself. In these conditions, indeed, cast iron may be said to stand unrivalled amongst metals in the perfection of the castings made from it, and they are quite sufficient to account for that perfection without calling in the now disproved supposition that it expands like ice at the moment of consolidation. The experimental determination of the specific gravity of liquid cast iron adverted to at the beginning of this paper affords us the means—and for the first time—of determining the total dilatation in volume as well as the linear dilatation of cast iron of the quality experimented upon, viz., the fine-grained, bright gray tough cast iron employed by mechanical engineers. As the specific gravities of this iron when cold and when melted were 7·170 and 6·650, so that the unit in volume when cold being taken as 1000, was increased to 1078·2 at the temperature somewhat above the melting point at which the iron was poured; the total dilatation in volume being thus 0·0782, and this divided by three—*i. e.*, neglecting all but the first term of the series—gives for the total linear dilatation 0·02606, which, taking the whole range of temperature between 60° and 2400°, and if we assume the dilatation uniform throughout the range, gives a coefficient of dilatation of 0·00001086 for 1° Fahr. This, however, is not quite correct, as the rate of dilatation increases rapidly within a few degrees of the melting point. The dilatation found as above is also in excess of that due to the precise range between 60° and the melting point of cast iron, the higher temperature in my experiment being somewhat above the melting point, exceeding it by probably about 200° Fahr. My direct object being simply to prove that melted cast iron is not denser—as has been stated—than the same cast iron in the solid state, and not that of ascertaining the exact dilatation due to the precise range between 60° Fahr. and the melting point; we are enabled, however, incidentally to deduce the latter with approximate accuracy. I must reserve, however, for a future communication some further remarks upon this part of the subject, as also upon the interesting phenomena of the movements observable in large masses of liquid iron, as in the

largest crane ladles, which have been erroneously appealed to as affording proof that liquid cast iron is denser as its temperature is higher.

MECHANICAL SCIENCE.

An Address delivered before the Mechanical Section of the British Association at its meeting in Belfast, Sept., 1874.

By Professor James Thomson, LL.D.

[Continued from Vol. lxviii, page 294.]

A great improvement has within the last two or three years been devised and practically developed by Sir William Thomson. Instead of using a hempen sounding line, or a cord of any kind, he uses a single steel wire of the kind manufactured as piano-forte wire. He has devised a new machine for letting down into the sea the wire with its sinker, and for bring both the wire and the sinker up again when the bottom has been reached. With his apparatus, in its earliest arrangement and before it had arrived at its present advanced condition of improvement, he sounded, in June 1872, in the Bay of Biscay, in a depth of 2,700 fathoms, or a little more than three miles, and brought up again his sinker of 30 lbs. weight, after it had touched the bottom; and brought up also an abundant specimen of ooze from the bottom, in a suitably arranged tube attached at the lower end of the sinker.

An important feature in his machine consists in a friction-brake arrangement, by which an exactly adjusted resistance can be applied to the drum or pulley which holds the wire coiled round its circumference, and which, on being allowed to revolve, lets the wire run off it down into the sea. The resistance is adjusted so as to be always less than enough to bear up the weight of the lead or iron sinker, together with the weight of the suspending wire, and more than enough to bear up the weight of the wire alone. Thus it results that the arrival of the sinker at the bottom is indicated very exactly on board the ship by the sudden cessation of the revolving motion of the drum from which the wire was unrolling.

Another novel feature of great importance consists in the introduction of an additional hauling-up drum or pulley arranged to act as an auxiliary to the main drum during the hauling-up process. The auxiliary drum has the wire passed once or twice round its circumference at the time of hauling up, and is turned by men so as to give to the wire extending from it into the sea most of the pull requisite for drawing it up out of the sea, and it passes the wire forward to the main drum, there to be rolled in coils, relieved from the severe pull of the wire and sinker hanging in the water. Thus the main drum is saved from being crushed or crumpled by the excessive inward pressure which would result from two or three thousand coils of very tight wire, if that drum unaided were required to do the whole work of hauling up the wire and sinker.

The wire, though exposed to the sea-water, is preserved against rust by being kept constantly, when out of use, either immersed in or moistened with caustic soda. The fact that steel and iron may be preserved from rust by alkali is well known to chemists, and is considered to result from the effect of the alkali in neutralizing the carbonic acid contained in the water, as the carbonic acid appears to be the chief cause of the rusting of steel and iron.

This new method of sounding, depending on the use of piano-forte wire, was first publicly explained by Sir William Thomson in the Mechanical Section of the British Association at the Brighton meeting two years ago; and in the interval which has since elapsed, it has come rapidly into important practical use.

I have to-day already brought under your notice a system of elaborately contrived and extensively practiced methods of signalling and otherwise arranging for the safety of trains in motion on railways. These methods, in the aggregate, as we have them at present, may be looked on as the result of a gradual development, which, through design and intelligent selection, has been taking place during the last twenty or thirty years, or more. In contrast with this I have now te mention a reform towards abatement of dangers at sea, which at present is only in an incipient stage of its practical application, but which I am sure must soon grow into one of the most important reforms of the future. I refer to the provision of means whereby every important lighthouse shall, as soon as it is descried, not only make known to the navigator that a light is visible, but also that it

shall give him the much more important information of what light it is; that, in fact, it shall distinguish itself to him from all other lights either stationed on land, or carried by ships out at sea. The rendering of lighthouses each readily distinguishable from every other light, by rapid timed occultations, was urged on public attention by Charles Babbage about twenty or twenty-three years ago, in connection with a like proposal of his for telegraphic signalling by occulting lights. His admirable idea, however, so far as it related to the distinguishing of lighthouses, has unhappily been left almost entirely neglected until quite recently. Although I say it was almost entirely neglected, yet very important steps in the direction of the object proposed were taken many years ago by Messrs. Stevenson, engineers to the Commissioners of Northern Lights, and the flashing and intermittent lights introduced by them, and now used, although too sparingly, in various parts of the world, constituted a very great improvement in respect to distinctiveness. The first practical introduction of an intermittent extinction of a gaslight, which is a method now likely to become fruitful in important applications with further developments, was made many years ago by Mr. Wilson at Troon; and an admirable application of this plan by the Messrs. Stevenson to carry out the principle of rapid signalling is to be seen in the Ardrossan Harbor light, which is alternately visible for two seconds, and then for two seconds is so nearly extinguished as to be invisible. The whole period —four seconds—is, I suppose, the shortest of any lighthouse in the world. This light fulfils the condition of being known to be the light which it is, within five or ten seconds of its being first perceived; and thus, in respect to distinctiveness, I trust that I may without mistake say it is the best light in the world. Mr. John Wigham has succeeded in constructing large burners for the combustion of gas in lighthouses in general, including those of the first order, and embracing both fixed lights and revolving lights. He has also, in both these cases, applied with the most striking success, the principle of occultation. Dr. Tyndall, in his reports to the Board of Trade, has dwelt frequently and emphatically on the ease with which gas lends itself to the individualization of lights. By its application, he affirms that by simple arrangements it would be possible to make every lighthouse declare its own name. Within about the last two or three years the subject has been taken up energetically by Sir William Thomson. He has

become strongly impressed with the enormous importance of the object in question. He has perseveringly labored in making trials in various ways, both by the method of partially extinguishing gas flames and by the method of revolving screens; and I have pleasure in stating that, as a result of his efforts, a self-signalling apparatus is now constructed for the Belfast Harbor Commissioners, who are preparing to bring it into immediate use at the screw-pile lighthouse at the entrance of the harbor of Belfast. I shall not now enter on any description of this arrangement, as I understand that the apparatus, which has already been temporarily erected for trial in the lighthouse, and has shown good results, is to be exhibited and explained to this Section by Mr. Bottomley, who, as a member of the Board of Harbor Commissioners, has taken an active part in the promotion of the undertaking.

I wish next to make mention of the very remarkable works at present in progress in the harbor of Dublin, under the designs and under the charge of Mr. Bindon Stoney. In order to form quay walls with their foundations necessarily deep under water, he constructs on land gigantic blocks of artificial stone, or, as we may say, of concrete masonry, each of which is about 350 tons in weight, and which are accurately formed to a required shape. After the solidification of the concrete, he carries them away and deposits them on an accurately levelled bottom of sea, so that they fit closely together, and form so much of the quay wall in height as to reach above the low tide level; and so as to allow of the completion of the wall above by building in the usual manner by tidal work, and to allow of the whole structure being carried out without the use of cofferdams. These operations are on a scale of magnitude far surpassing anything done before in the construction and moving of artificial stone blocks. They are carried out with machinery and other appliances for the removal and the placing of the blocks, and for other requirements of the undertaking, which are remarkable for boldness of conception and ingenuity of contrivance. The new methods of construction devised and applied in these works by Mr. Stoney are recognized as being admirably suited for the local circumstances of the site of the works in the harbor of Dublin, and their various arrangements form a very important extension of the methods of construction available to engineers for river and harbor works.

While progress has been made with gigantic strides in many directions, in engineering and in mechanics generally; while railways, steamboats, and electric telegraphs have extended their wonders to the most distant parts of the world; and while trade, with these aids, is bringing to our shores the produce even of the most distant places, to add to our comforts and our luxuries; yet, when we come to look to our homes, to the places where most of our population have to spend nearly the whole of their lives, I think we must find, with regret, that, in matters pertaining to the salubrity and general amenities of our towns and houses, as places for residence, due progress in improvement has not been made. Our house drainage arrangements are habitually disgracefully bad; and this I proclaim emphatically, alike in reference to the houses of the rich and the poor. We have got, since the early part of the present century, the benefit of the light of gas in our apartments; but we allow the pernicious products of combustion to gather in large quantities in the air we have to breathe; and in winter evenings we live with our heads in heated and vitiated air, while our feet are ventilated with a current of fresh, cold air, gliding along the floor towards the fire-place to be drawn uselessly up the chimney. A very few people have commenced to provide chimneys or flues to carry away the fumes of their more important gaslights, in like manner as we have chimneys for our ordinary fires. In mentioning this, however, as a suggestion of the course in which improvement ought to advance, I feel bound to offer a few words of caution against the introduction of flue pipes for the gas flames rashly, in such ways as to bring danger of their setting fire to the house. People have a strong tendency to require that such things as these should be concealed from view. In this case, however, special care should be taken against rashly placing them among the woodwork between the ceiling of the apartment and the floor of the room above or otherwise placing them in unsafe proximity to combustible materials. In many cases it would be better to place the flue exposed to view underneath the ceiling, and by introducing some accompanying ornamentation, to let the flue be regarded as a beneficent object not unpleasing to the eye.

The atmosphere of our large towns, where people live by hundreds of thousands all the year round, is not yet guarded against needless pollution by smoke, jealously, as it ought to be. Many of the wealthier inhabitants take refuge in living in the country, or in the

suburbs of the town, as far away as they can from the most densely built and most smoky districts; but the great masses of the people, including many of all ranks, must live near their work, and for them at least greater exertions are due than have yet been made towards maintaining and improving the salubrity and the amenities of our towns. As to the abatement or prevention of smoke from the furnaces of steam-engines, the main requisites have long been very well known; but sufficient energy and determination have not yet been manifested towards securing their due application in practice. In too many cases futile plans have been tried, and on being soon abandoned have left a strong impression against the trying of more experiments; and this may account in part for the introduction of real improvements having been so slow. Smoke occurs when fresh coal is thrown suddenly, in too large quantity at once, upon a hot fire. By extreme care a fireman may throw coal into his furnace so gradually as to make very little smoke; but mechanical arrangements for introducing constantly and uniformly the new supply of fresh coal have been devised, and several of these have been such as to reduce the smoke emitted to almost nothing. I have seen in the neighborhood of Glasgow, at a large manufacturing establishment at Thornliebank, one method which is applied to about thirty ordinary 40 horse-power boilers, in which upwards of 100 tons of coal are daily burned, and from the chimneys of which not more smoke is emitted than from many a kitchen fire. This method is under the patent of Messrs. Vicars, of Liverpool, and it seems to work very well. It has been about two years in work there. It was introduced at a time when coal was exceedingly high in price, as much to effect economy in fuel as to prevent smoke; and although the first cost was somewhere about £130 per boiler, the proprietor considers himself to be already more than recouped for his outlay, as a saving of fully 12 per cent. in the fuel consumed was effected. At the same works I have also seen in operation the method of Messrs. Haworth and Horsfall, of Todmorden, which has, I am told, in certain circumstances, some advantages over the other. In this, as in the other, the coal is fed in uniformly by mechanical arrangements. The mechanism is different in the two cases, but the result in the motion communicated to the coal is very much alike in both. The bed of coal, which is gradually supplied in front, is caused to travel along the bars towards the inner end of the furnace, and the

combustion proceeds in a very uniform manner in conditions highly favorable to economy of fuel, and almost without the emission of any visible smoke.

These two methods I have mentioned because they both appear to work very successfully in practice, while they both bring into effect the principle of action of the fuel which has long appeared to me to be the best that can be adopted for ordinary cases of steam-engine boilers.

I have now occupied, I think, enough of your time, and so I will conclude. I have endeavored to select out of the wide range of subjects which fall within the scope of the Mechanical Section of the British Association, a few which have come more particularly under my own notice, and on which I thought it was in my power to give intelligence that might be interesting as to past progress, and suggestions that might be useful towards extension of improvements in the future.

ON DIAMOND DRILLING.

By Chas. E. Ronaldson, M. E.

One of the most interesting, as well as important, improvements in ground or rock drilling, is the substitution of the diamond, as a cutter, in the place of steel, iron, etc. Ranking first on the scale of hardness, its durability being unsurpassed, it is thereby eminently fitted to take precedence of any mineral or metal which had ever been used up to the time when the idea of using the diamond for this purpose was conceived.

Since its introduction, many important improvements have been added, and though still in its infancy it bids fair at no distant period to play a very important part in every form of drilling, boring, and, maybe, turning. It admits of uses to which it has never been applied, but which it is merely a question of time to perfect, and to bring into practical use. Though diamonds are not inexpensive, yet the wonderful results accomplished by their use, prevent them from being

considered too costly to be employed for their present use as cutters.

It was my pleasure, a short time since, to witness the drilling of a hole (at Delano, Schuylkill county, Pa.) for the purpose of ascertaining the existence of coal.

Upon the Delano Tract, and about two hundred yards from the position of the drill, two veins out-cropped upon one side of the hill; while upon the other side a tunnel is in progress, the hill being drilled to determine the distance the tunnel should be run to meet the veins.

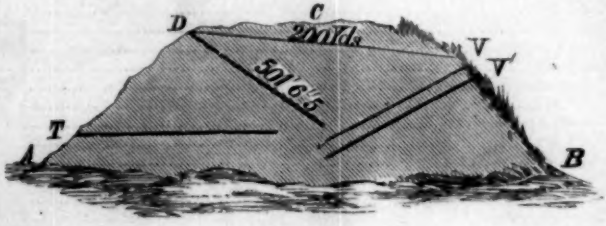


Fig. 1.

In the above Cut, Fig 1, A B C represents a Section of the Hill. T, is the location and direction of the Tunnel. D, the position of Drill, set at an angle of 60°. V V′ are the location and direction of the Coal Veins. A very peculiar fault, or displacement of the veins occurs, for by calculation, the hole should have struck them at a depth of not more than three hundred feet, whereas they reached a depth of 501 feet 6·5 inches, and found coal wanting, merely passing through a stratum of slate and bony coal one foot in thickness, which was supposed to be the Buck Mountain Vein, which vein is successfully worked less than one mile from here.

In drilling this hole, the general average worked was ten hours per day (including lost time), and the time worked amounted to 25 days and 5 hours, which was very quick work, when we consider the extreme hardness of the rock drilled through, being, in many places, strata almost pure quartz or silica. I heard of a hole drilled to 500 feet, which took three months to accomplish, having a double shift, and the rock comparatively soft.

The engine used at Delano was a "Root Square," of ten horse power, with Allison's, of Pottsville, patent cylinders. The average speed was 350 revolutions per minute. The average pressure upon the hydraulic feed was 100 pounds. The pressure in pump to flow the sediment was 120 pounds.

The various strata passed through are as follows, viz.:

No. of Stratum.		Thickness. Feet.	Inches.
1	Fine conglomerate rock	10	4½
2	Coarse pebbled conglomerate	1	1½
3	Conglomerate (shade varying)	4	8
4	Fine conglomerate	7	8
5	Coarse pebbled conglomerate	4	9
6	Fine conglomerate	6	7
7	Conglomerate (varying)	23	8
8	Red conglomerate or oil rock	1	...
9	Sand slate	...	9
10	Coarse pebbled conglomerate	7	8
11	Conglomerate (varying)	9	4½
12	Sand slate	1	8
13	Coal slate	2	...
14	Coarse conglomerate	28	9½
15	Sand slate	...	6
16	Coarse conglomerate	2	...
17	Sand slate	3	8
18	Coarse conglomerate	15	6
19	Sand slate	3	6
20	Conglomerate (varying)	4	...
21	Sand slate	3	10
22	Flint quartz rock (*very hard*)	20	2
23	Conglomerate	6	6
24	Sand stone	5	2
25	Fine conglomerate	16	6
26	Coal slate	1	3
27	Sand stone	4	9
28	Coal slate	7	7
29	Sand stone	6	...
30	Soft slate	3	9½
31	Sand slate	3	...
32	Sand stone (7 foot vein) [overlying the Buck Mt. Vein.	7	...
33	Hard slate	8	6
34	Coarse conglomerate	13	8
35	Sand stone	2	...
36	Coarse pebbled conglomerate	24	10½
37	Sand stone	1	...
38	Coarse conglomerate	29	3½
39	Slate (soft)	1	...
40	Coarse pebbled conglomerate	7	2
41	Hard slate	2	6
42	Coarse pebbled conglomerate	22	10½
43	Flint quartz conglomerate (very hard)	7	3¾
44	Conglomerate with seams of slate	...	6
45	Hard slate	...	3
46	Conglomerate (varying)	1	5
47	Fine grain conglomerate	3	...
48	Sand stone	2	8
49	Coarse pebbled conglomerate	10	10
50	Slate and bony coal (supposed Buck Mt. Vein)	1	...
51	Conglomerate (varying)	47	2
52	Sand rock	1	...
53	Coarse pebbled conglomerate	7	8
54	Blue conglomerate rock	11	½
55	Sand rock	1	4½
56	Seams of slate and sand stone	36	9½
57	Sandstone slate and seams of coal	1	2
58	Coarse pebbled conglomerate	18	6
59	Sandstone with seams of slate	3	...
60	Coarse pebbled conglomerate with seams of slate	14	...
61	Coarse conglomerate	7	6
62	Sand stone	...	6
63	Coarse conglomerate	...	7
		501	6.5

Possibly a brief description of the Core-barrel, Bits, Rods, etc., may be of interest, so we will begin with the

Core-barrel, which is a hollow cylinder of iron, 12 feet in length, with diamonds set upon the outside, three or four feet apart; to protect the barrel from wear, there is a groove (square) cut upon the outside similar to the thread of a screw, it is 1-16th of an inch deep, and allows a free passage for the water to the Bit upon the lower end. An inside thread is cut upon the upper end, to allow the insertion of the couplings, to connect it with the rods.

The *Bits* are made of solid steel, drilled, and contain generally ten diamonds. Those diamonds for cutting the outside clearance are generally the *Bort's*, being harder than the ordinary diamond, in order to keep the size of the bit. The Fall or *end* diamonds are the carbon. There are also a few diamonds placed up, upon the outside of the bit, to prevent wear. Four diamonds are generally used to cut the core and allow its free passage into the core-barrel.

The *Core-lifter* is separate from the bit, and contains upon the inside a loose ring, split on one side; the ring is turned tapering, and works upon an inclined plane, in this manner: When the bit is cutting, the core forces the ring up into the upper cavity or top of the incline, allowing the free passage of the core into the Barrel, but so soon as the motion is reversed, the core slipping back, the ring falls into the lower cavity of incline, and jams the core, holding it securely until it can be removed at the surface.

Rock cores have been taken out 12 feet in length, and one measuring that length (12 feet) was taken out by a Mr. Nash, near Pittston, Luzerne county, Pa., and is the longest yet taken out in this State. Mr. N. has also taken out the longest *Coal core*, it measuring 23 inches. The 12 feet core was of conglomerate rock.

Mr. Thomas Nash (a brother of the above), and having charge of the drilling at Delano, took out a piece of core 9 feet in length, of conglomerate rock.

The *Rods* are hollow cylinders of iron, a thread cut upon the inside of each end for a short distance, to allow the introduction of the Coupling, which is of iron, 6 inches long, with a $\frac{5}{8}$ hole drilled in the direction of the length; they each weigh $2\frac{1}{4}$ pounds. The rods are 8 feet in length, and weigh 5 pounds to the foot; they are $1\frac{1}{8}$ inches in diameter.

In drawing out the Rods they are disconnected at every 16 feet, and in order to prevent the remaining undrawn rods from slipping back into the hole, they are caught and securely held by what is known as the Safety Clamp, an ingenious invention of Mr. Bullock, Superintendent of the American Diamond Drill Company of New York.

The *Clamp* consists of a Strap, in which are two brasses, one of which works upon an incline plane, at an angle with the other. A set-screw at the back of the strap jams the brasses to the rod, and when the pressure is removed, or the screw loosened, a small spiral spring forces the opposite brass up the incline, and the pressure upon the rod being removed, it can be easily withdrawn.

The Core-barrel is Mr. Frisbie's invention, he being at present, Superintendent of the Pennsylvania Diamond Drill Company, of Pottsville, Pa. To this gentleman is attributed the success and perfection of the diamond drill, he having added many valuable improvements.

The bits are manufactured at Pottsville, Pa. Formerly only one cylinder was used in the hydraulic feed, but Mr. Allison has combined two, whereby an equal and uniform pressure and motion is given in feeding down the drill, which is a very valuable invention.

This article has been hurriedly written, but I trust it may be of interest to those who have no opportunity to witness the operation.

THE MANUFACTURE OF CAOUTCHOUC AND ITS INDUSTRIAL USES.*

By Eugene Pavoux,

Director of the General India-rubber Manufactory at Brussels.

The multifarious uses of india-rubber, and the numerous industries in which it is employed, are such as to give an interest to the consideration of the properties of this material and of the means employed to give it the appearance and the forms under which it is rendered useful.

Its principal quality is its elasticity at an ordinary temperature. This special quality, to which it owes its repute, disappears almost

* Reprinted from the *Journal of the Society of Arts.*

entirely under a temperature approaching to that of melting ice, and only reappears when the india-rubber is subjected to a heat of from 30° to 40° Cent., when it again becomes supple. It softens in proportion as the temperature rises, becomes viscous, and ends by taking the consistency of treacle. This sensibility to the influence of temperature must have prevented its being used in industrial pursuits, if means had not been found of neutralizing it by a special manufacturing operation. Above 200° it is decomposed, and passes off in a volatile form.

Its density varies between 0·925 and 0·950. According to Faraday, it is composed of 87·2 of carbon and 12·8 of hydrogen.

India-rubber is a sap which flows from various sorts of trees which grow in abundance in the regions near to the equator, notably the *Ficus elastica*, the *Siphonia cahucha*, &c. Its qualities are distinguished by the places where it is grown, and sometimes, though rarely, by some external characteristic. The terms most frequently used in the manufacture are: Para, Madagascar, Carthagena, Guyaquil, Borneo, West India, Assam, &c. It is obtained as follows:

The trunk of the tree is pierced, and the sap (which contains about 40 per cent. of india-rubber) is allowed to run off into a vessel, but more frequently into a hole dug at the foot of the tree. Balls of dried clay made in the shape of pears are plunged into the liquid, and afterwards passed over a fire made of the branches of trees, in order that the layer of india-rubber which has been deposited on the clay may be made to coagulate rapidly. This operation is repeated until a certain thickness has been acquired. The balls are then plunged into water, and the clay, thus softened, is easily got rid of by simple pressure.

Sometimes a thin board is used as a nucleus, on which the sap is deposited and agglomerated; in this case, the mass of india-rubber thus collected is cut on three sides to admit of the board being drawn out, and in this way double sheets are obtained, which open almost in the same way as a book. The purest india-rubbers are those which are gathered in this way; such as Para and Madagascar, the simple aspect of which reveals the almost total absence of extraneous matter.

When the sap is allowed to run out on the ground, it collects in irregular strips, mixing with the impurities of the soil. These strips are put into sacks and sent off to the various places of consumption.

When they are very thin they are rolled up like a skein of thread, and the appearance of the india-rubber in balls serves to remind one of a clue of worsted.

In these different states india-rubber comes to Europe. It is indispensable to rid it of every kind of detritus, sand, wood, pebbles, bark, etc., which have become mixed with the gum whilst running from the tree. This is the object of the first process in the manufacture. The raw material, after being softened by immersion in a large tub of hot water, is cut up with a saw into cubic pieces of about an inch and a half, then flattened between two cylinders, placed horizontally, the distance between which is regulated at will by set-screws. These cylinders are of different velocities; it follows, therefore, that, independently of the pressure which the india-rubber is made to undergo, it is hacked and torn to such an extent that all extraneous matters are removed, and under the continuous action of a stream of water, they are easily carried off. Under this process, which is repeated eight or ten times, every time bringing the two cylinders nearer together, all the impurities vanish, and the rubber assumes the form of an irregular sheet, grained, and pierced through with innumerable holes. This sheet, when hung up to dry in a place where the air circulates freely, thanks to its texture, very soon loses the water with which it is impregnated.

It is important that the material should be kneaded, in order to bring together in a single piece the scattered elements of the sheet, and impart to it perfect homogeneity. This is done by means of a kneader called a "devil," which consists of a cylinder fixed horizontally, divided or not into separate compartments by partitions perpendicular to the axis. Over the total length of this cylinder, and a quarter of its circumference, there is an opening by a sort of door on hinges, through which the dried rubber is introduced. A shaft, provided with a series of sharp-pointed teeth disposed in rows alternating one with another, runs through the whole length of it. This shaft, which makes seven or eight revolutions a minute, carries along with it the grained sheet of which I have spoken, and causes it to traverse the entire free space of the cylinder. In doing this the mass of caoutchouc takes a rotating motion, produced by the teeth, which successively take it up and draw it towards them. There results from this a perfect process of trituration, which forms the sheet of rubber into a compact mass, all the parts of which are thoroughly mixed.

In order that this operation may be effected under proper conditions, it is necessary that the roll of caoutchouc which has to be put into the cylinder should be a little wider than the cylinder itself, in order that it may press against the sides, and, consequently, be regularly drawn in by the motion of the shaft. This proceeding lasts, on an average, a couple of hours; the longer it is continued, the less time is required for the process which has to follow, by reason of the thorough homogeneity into which the material has been brought.

The devil, as it is called, is usually formed with a double casing, which is heated by means of a steam jet.

I have been induced to abolish this, because I find that the heat developed by the work itself is sufficient to facilitate the kneading of the material, whilst if it is increased by that arising from the steam, the temperature is such as to cause the rubber to become soft and viscous, and this deteriorates its quality and interferes with the following operations.

On leaving the devil, the material passes to the compressing cylinders, which are placed in couples on a horizontal plane, and may be brought to any distance from each other by means of screws worked by a crank placed within the reach of the workman.

These cylinders are hollow, and are heated internally with steam by a pipe running through a packed box. Two pipes running into one serve to discharge the steam, the ingress and egress of which are regulated, according to the necessities of the work, by taps. The rubber is thus thoroughly compressed until it presents the aspect of a rolled-up sheet, of firm texture, close, and exceedingly smooth. This gives the finish to the preceding operations.

Pure india-rubber is only used for certain special purposes. The requirements of industry demand various qualities of products, possessing properties suitable to the different uses to which they are to be applied; it is the mixture of blocks of compressed rubber with foreign matters in certain proportions which enables the manufacturer to produce qualities answering to the variable conditions under which they have to be used. Rolling forms a mixture of these several substances, which is regular and uniform throughout; it is also during this operation that the coloring matter is added, which gives to india-rubber its various shades of gray, black, red, etc., in which it so frequently appears. It is in the form of powder that all these matters are mixed with it. At every passage between the cylinders a portion

of it escapes, and falls on a slightly inclined table, which is gathered up by the workman and thrown again into the mass, which, becoming wider by the pressure, is rolled up by the workman as it issues from the cylinders, between which he puts it in afterwards lengthwise. It is, therefore, rolled in every possible way, which tends to give to the texture a greater degree of homogeneity.

The india-rubber paste obtained by this process is afterwards worked up either by rolling or moulding.

In the first case sheets are made of any length and thickness that may be required, whilst in the second it is cast in any mould the manufacturer may desire.

As regards the rolling, the paste is made to pass between the two cylinders of a calender, by which it is spread out into a sheet of the same dimensions as the cylinders; these sheets may be made to any length, of course, by feeding the calender continually with one block of material after the other. The adhesive tendency of india-rubber is so strong that when the finished sheet has to be wound on to a roller, it can only be done by the interposition of a piece of cloth, which serves to separate the different windings of the sheet. It is then placed on a table and unrolled, in order to be worked up into the form and dimensions required. The same calender serves for coating cloth, which is used for many purposes, amongst others, for making tubes and straps; the paste, which passes through the cylinders at the same time as the cloth, is spread upon it in a layer, the thickness of which is regulated by the distance, and the tenacity with which it sticks is in proportion to its adhesive qualities.

Certain pieces are suitable for special forms, which they can only be made to take by moulding. In order to manufacture these, the india-rubber paste is put into a mould, which is filled more or less exactly. The exposure of this mould to a temperature varying between 125° and 150° causes the material to expand and penetrate into every part of the mould, and to take the exact form that is wanted. If a hollow article is required, a little water is introduced, which, being changed into vapor by the heat, compresses the paste, and makes it adhere to the sides of the mould, of which it takes the exact outline.

There is one remark which it is important to make: it is that the paste adheres easily by simple contact, as long as the material has not undergone the process of vulcanization. The shape then (with the exception of the cutting of certain objects from sheets) should

always be given previous to vulcanizing, which is the last process of manufacture.

Raw india-rubber seems to consist of two parts, each possessing distinct properties: the one compact and elastic, the other heavy and semi-liquid. It is to the presence of the latter element that is to be attributed the extreme facility of adhesion by which it is characterized, and it serves to explain the way it is affected by the action of the cold, and the modification it undergoes under the influence of a high temperature. The transformation of the viscous part, which is most sensitive to the variations of heat, has the effect of preventing those grave inconveniences arising out of it, and of making india-rubber a substance that can be utilized under any conceivable circumstances. That is the object attained by vulcanization.

The agent employed for vulcanizing is sulphur. Its action on india-rubber is analogous to that with which it acts on fatty substances which, when mixed with it in the proportion of one to five, and heated to a temperature of about 200°, produce a substance offering a good deal of resistance, and presenting almost the aspect of india-rubber. The result is that vulcanized rubber does not harden with the cold, neither does it soften with the heat; it preserves its elasticity, resists acids, and can no longer be made either to dissolve or to adhere.

The incorporation of sulphur is effected either in the solid state or in a state of fusion, according to the nature of the articles that have to be vulcanized. The first method, which is the most in use, consists in mixing flowers of sulphur with the rubber at the same time as the other matters which are added in rolling; it thus becomes uniformly mixed with the mass, but as the reaction to which it must give rise can only be produced at a high temperature, it does not so far modify the properties of the india-rubber paste, which still continues adhesive. The article which is being made is put into a boiler made of sheet-iron, capable of supporting a pressure equal to from four to five atmospheres, and closed by a bolted lid; a jet of steam is let in, the tension being measured by a steam gauge, and the length of time during which the operation continues varies according to the number of pieces, but it is estimated at a couple of hours on an average. The necessary temperature is about 150°. When it is required to put several objects one on the top of the other, they are sprinkled all over with silicate of magnesia to prevent them from adhering to their supports.

The articles manufactured in moulds with an open surface are vulcanized in presses composed to two hollow, horizontal plates, the

uppermost of which is moveable, and worked by screws which allow it to work up and down. The moulds are placed between these two plates, and in this manner the paste is compressed. The necessary temperature is produced by the steam which circulates in them from pipes placed at one of the extremities, and passing at the other end through outlet pipes.

I have had fixed up in my manufactory a large press of this kind, by which I am enabled to vulcanize sheets, with great economy of time; the plates are about 7 feet long by 4 feet wide; their internal surface being carefully planed and dressed they give to the sheets a glossy appearance, with remarkable uniformity of character.

To produce vulcanization by the liquid method, the sulphur is put, in a state of fusion, into large boilers, underneath which are large fire-places; the articles already made are plunged into these boilers, care being taken to keep them covered with the liquid by means of weights. This precaution is indispensable, in consequence of the difference in density of the sulphur and the rubber. The absorption of the metalloid takes place, and is gradually completed until the combination is effected, which takes from two to three hours. Experience will be the best guide as to the time when the operation has been accomplished. Care must be taken that it is not continued too long, because in this case the rubber becomes hard and loses its elasticity. As soon as the articles are taken from the boiler, they should be plunged into cold water; this causes the layer of sulphur deposited on the surface to crack, after which it is easily removed by scraping.

It is as well to remark that only small objects admit of this method of vulcanization; those of larger size must undergo the first process.

There are also other methods of vulcanization which, although less applicable to industrial products, nevertheless deserve to be mentioned. Chloride of sulphur mixed with sulphide of carbon, in the proportion of one to fifty, will produce this result. When immersed in this compound, the rubber becomes impregnated in a few minutes, after which it is plunged into a reservoir of cold water: the object of this is to neutralize the effect which a too prolonged immersion would have upon the surface, which would be to vulcanize it too much. During the immersion, the mixture penetrates into the centre of the mass. It is only articles that are not very thick that can be subjected to this process.

It is exactly the same as regards the process which consists in the use of alkaline sulphides; the operation lasts about four hours. In

consequence of the restricted application of this method, it may be regarded as more theoretical than practical.

After vulcanization, the surface of the rubber sometimes presents slight efflorescences of sulphur; these are easily removed by washing with an alkaline solution.

To dissolve india-rubber, no better agent can be employed than sulphide of carbon, to which must be added 5 per cent. of anhydrous alcohol; a product is thus formed which, when subjected to evaporation, leaves a residuum of rubber possessing all its primitive qualities. It may also be dissolved by any of the essential oils, but the material which results from their evaporation is oily and viscous, so that their use has been entirely abandoned.

Before proceeding to treat of the industrial uses of india-rubber, it will be interesting to say a few words respecting indurated rubber, which constitutes a special branch of manufacture; independent of its restricted application to great industrial purposes, it is applied to the manufacture of a large number of objects of all shapes and dimensions, adapted to ordinary daily wants. The manufacture of indurated rubber may be disposed of in two words. The quantity of sulphur which is mixed with the paste is larger, and amounts, according to circumstances, to from 35 to 40 per cent., and the vulcanization is prolonged beyond the ordinary limits, the maximum being from six to seven hours. For great thicknesses, a longer time may be necessary, but this is an exception. The operation is a very delicate one, and demands a great deal of care to prevent the article being burnt, as it in that case would become worthless.

Indurated india-rubber is worked with the file, the saw, and the lathe, exactly like metals and other hard substances.

The applications of india-rubber to industrial purposes are exceedingly numerous, and are increasing daily. "Its elasticity, its tenacity, added to which, the property it possesses of being completely homogeneous and impermeable, recommend it for a vast number of uses in which it would be difficult to find a substitute."*

The various kinds of joints which are used for water pipes, gas pipes, and steam pipes, may be classed in several categories, and india-rubber is used in all of them. The flat washers for flange joints are made in various qualities of material, but most frequently by means of one or several cloths dipped in the paste, and intended to

* A. Stevart: "Results of Experiments in the Elasticity of Vulcanized India-Rubber."

prevent the lateral extension which would take place in pressing the surfaces together, as well as by the heat, in the case of joints with steam at high pressure; the number of cloths depends upon the thickness of the washer. Instead of being parallel at the surface, the cloths are frequently disposed concentrically, and are placed at a distance from each other of from two to three millimeters. The same result may be obtained with felted india-rubber, that is to say, mixed with fibrous matter, such as woollen or cotton waste, etc., which by their resistance admit of greater tenacity, and cause the lateral extension to be less felt.

In laying the flange pipes, it often happens that, through the negligence of the workman, the centre of the washer does not coincide with the axis of the pipe, and causes a projection in the inside. When this defect presents itself at the lower part of a steam pipe, it prevents the waste water from running off; it is better, therefore, to adopt the system in which the washer is kept in its place by a flange at one of the ends of the pipe; the play left between the two pipes admits of expansion, without causing any danger.

The washers with circular section which are used for joining the pipes are especially employed in the ingenious system of which M. Leon Somzé is the inventor. The washer is introduced by being rolled into the annular space between the two ends, called male and female, of the jointing pipes, and is kept by the conical form of the male end in a perfect state of compression.

In making Delperdanges' joints it is necessary to use a ring forming a band, which, placed on the flanges, which are close to each other, of two pipes, is compressed and kept in its place by an iron bridle, terminated with two claws, which are pressed and brought together by a bolt. A copper sheet keeps the rubber against the pipe, where the claws are. This system has been at work in the water distribution of Lille and Valenciennes. Lastly, certain joints are made by means of a cord, either round or square, made of india-rubber alone or of felted rubber, which is placed in a groove in the two surfaces which have to be joined. The compression of this cord hermetically closes the two ends of the pipes.

India-rubber is also largely employed in transport. On the railways, the buffers are furnished with a series of washers of rectangular shape about two inches in thickness, separated from each by sheet-iron plates, which allow each washer to be compressed singly, so that every advantage is derived from the characteristic property of the

material. To allow the passage of the buffer rod, these washers are pierced in the centre with a hole, the diameter of which is larger than that of the plates, in order that the depression of the washer may not drive back the rubber against the rod. For the same reason, the sheet-iron plates are of larger diameter to prevent the rubber from being pressed back beyond their outer edge.

In the construction of passenger carriages, arched pieces are used, which, being fixed in the inside of the wainscoting of the doors, receive the shock of the glass windows as they are lowered, and preserve them from the breakage to which they would be exposed without this precaution.

In tramways, the springs are replaced by buffers, taking the form of two truncated cones, united by their bases; these buffers, placed between the box and the axles, weaken, by their elasticity, the jolting of the cars, and render the motion exceedingly smooth and gentle. The tenacity, strength, and duration of the springs depend on the proportion of foreign matter which the material contains; there ought to be only a small proportion, but a certain quantity is essential, in order to give them the requisite body and solidity. The use of these springs in the wagons belonging to mines and quarries would, undoubtedly, diminish the deterioration in the rolling stock by preventing the violent shocks which are frequently caused by the dilapidation of the roads.

India-rubber is also used for the outer rim of wheels for vehicles used in railway stations, large manufactories, entrepots, etc. In this case the metallic rim of the wheel takes the shape of a groove, in which the elastic band is embedded; the diameter of the latter is ordinarily calculated at four-fifths of that of the wheel.

Road locomotives appear to have acquired an increase of tractive power by the application of similar bandages. There is no vehicle, even down to the velocipede, which does not make use of this material, endowed as it is with so many precious qualities.

It enters largely into the construction of machines, and especially of pumps. The valves vary in form as well as in thickness; some are round, others are square or rectangular. The seat on which they rest has several apertures, they are thus supported otherwise than on their edges, which preserves them against the pressure. The metallic breastwork which forms the seat ought to present no projecting edge, which would enter into the material, and cause speedy deterioration. These valves are, for the most part, made of simple india-rubber, but

sometimes cloth is put between to give them greater tenacity. The special circumstances under which they have to be employed will guide the maker in the selection.

Certain valves are composed of a simple metallic sphere, covered with india-rubber, which, being raised by the liquid, falls down again as the piston descends, on the orifice it is intended to close. In order that these valves may retain sufficient suppleness to admit of their hermetically closing the orifice, it is better that they should consist of a hollow india-rubber sphere, filled almost entirely with small shot.

An ingenious application of india-rubber is that which has been made by M. Field, in respect to a valve composed of two india-rubber discs slightly conical, and placed face to face. These discs are flat and pierced with a hole in the centre, but they are compressed, and made to assume a conical shape by metallic pieces in the interior. Their external edges are in contact with each other, and maintained thus by the pressure which is exercised on their outer faces. The principal merit of these valves is their perfect resistance to the strongest pressure; in fact, their action being exerted in every part at the same time, the lips of the valve are forced against each other, with an energy which is greatest when the pressure is strongest. Messrs. Whitley, of Leeds, have applied this valve to all kinds of pumps, for pumping either cold or warm water or other liquids at pressures rising as high as ten and even thirteen atmospheres.

The Perreaux valve is exclusively composed of india-rubber. The side gets gradually thinner until it comes to the sharp edge, which is split, and opens out a little under the pressure of the liquid; it closes again as soon as the piston begins to descend.

As regards pumps which are intended to pump acids, an india-rubber bucket is used, in which the rod of the piston is placed; these pieces are moulded.

Hydraulic press rings made of india-rubber replace advantageously those covered with leather, which are high in price. These rings are moulded in exactly the form required, and they are much more flexible than leather ones, even of the very best quality.

India-rubber pipes, by reason of the multiplicity of their uses, and the diversity of their composition, form an important branch of manufacture. Those that are used for gas, acids, etc., and have to bear only a feeble pressure, are made of pure rubber by simply rolling a strip of paste round a mandrel; the soldering is easily effected by contact merely, and is consolidated by the pressure of two small blades,

worked by hand. To prevent the paste from adhering to the mandrel, care is taken to dust it over first with powdered talc. Sometimes several strips are placed on the top of the other, the number being determined by the thickness of the pipe which is being made.

When the tubes are intended to be subjected to a certain pressure, they are consolidated by the insertion of one or more layers of cloth, the cohesion of which prevents the swelling of the pipe, the wearing away of the sides, or their rupture under extraordinary pressure. These pipes are generally formed as follows: A round of india-rubber on the mandrel forms the first tube, over which a strip of cloth is rolled, done over with india-rubber by a calender; a fresh round of pure paste is followed by a second covering of cloth, and the operation is repeated according to the number of folds the pipe is intended to have: this number of folds depends on the diameter, and increases generally with it. The outer envelope is india-rubber. By increasing the rounds of cloth, we obtain pipes capable of resisting the strongest pressure.

When a liquid has to be pumped up, it is necessary to guard against the crushing of the pipe, which the atmospheric pressure would inevitably cause. For this purpose a spiral is used, made of galvanized iron or copper, which is either simply placed in the interior of the tube, or imbedded in the thick part of the rubber. Generally, the outer part of the tube is formed of coarse cloth, which serves as a protecting envelope, as these pipes are nearly always intended to be trailed on the ground; they are much used for fire engines and pumping engines.

All these kinds of tubes can only be vulcanized after they have been finished. They are placed on a vehicle which runs on rails, and run into a boiler 20 yards long, specially prepared for them.

I manufacture a particular kind of pipe, for which I have taken out a patent. It is made of tanned hemp, with an inside casing of india-rubber, and can be advantageously applied to a great number of uses. Being tanned, it is enabled to resist moisture, which has not the slightest effect upon it. It is much lighter than leather, consequently, in case of fire, a man can carry a much greater length, and can mount a ladder with it much more easily. The application of india-rubber sheets to the interior of these tubes prevents the infiltration of water into the pores of the tissue; it also prevents any loss of liquid, and protects them from injury. The resistance is very considerable; a diameter of 1¾ inches will bear a pressure of fifteen

atmospheres, and one of ¾ inch will bear twice the amount of pressure. They are used for fire engines, for brewery funnels, water pipes, steam pipes, etc.

The ropes used for packing, which are made of cloth, done over with india-rubber, are made without core, that is to say, without any inner nucleus in pure rubber; they are generally used concurrently with hemp for furnishing stuffing-boxes, and with the best results; the flexibility of the hemp admits of the expansion of the rubber, and this, in its turn, corrects the want of compactness presented by textile fabrics.

Straps merit special notice. They are composed of a certain number of folds of cloth done over with rubber, alternating with layers of pure rubber. The number of folds, and, consequently, the thickness of the strap, is in proportion to its width: for this reason, when the width is above 10 centimetres, there are at least three folds; above 15 centimetres, four folds; and above 25 centimetres they have from five to seven folds. They are made of all lengths in a single piece, and are joined exactly like those in leather, They work as well in water as in places heated to a high temperature. Their use is becoming very general, for besides being less costly than those in leather, they adhere much better. It is important that the several cloths of which they are made should not slip one over the other, and they should be made to adhere firmly by the intermediate layers of rubber. This object is attained by their being vulcanized in the press.

India-rubber has been used for some time in covering metal rollers employed for sizeing and finishing cloth; woolen rollers are replaced by metal ones, which prevent the necessity for using paper or cotton for stuffing the inside of the dressing cylinder; it also does away with the use of linen or woolen cloth for the external covering of the roller, one or more sheets of india-rubber being now used instead. Manufacturers find great advantage in this. The size, whether colored or not, adheres sufficiently to the rubber to admit of either threads or tissues being well sized without any absorption of the material by the rubber; the size, therefore, as well as the coloring matter can be taken off the roller by simply washing it with water, which permits the immediate use of the same apparatus for sizeing in the other colors. The india-rubber covering, by adhering thoroughly to the metal, and having none of these protuberances caused by the crossing of linen or woolen covers, presents a perfectly smooth and regular surface, and gives greater uniformity to the sizeing.

The thickness of the covering varies from 12 to 15 millimetres, according to the diameter of the cylinder. To have it in good order, the surface of the cylinder should be perfectly smooth.

Billiard makers secure great elasticity for their side cushions by using india-rubber, to which they give various shapes at discretion. The material used for this purpose ought to have rather greater density than the raw rubber.

The other industrial uses to which it is applied are innumerable; I need only mention the buckets and funnels used for acids, plugs with and without holes, rings and flanges for the joints of washing machines, rollers for twisting frames, sets of pulleys for ribbon saws, guide straps and aprons for paper-making machines, joints for filter presses used in sugar manufactories, moulds for hat manufacturers, aprons for sugar works, etc., etc.

As regards the application of indurated rubber, we may mention the rollers for spinning frames, made in two parts of different composition and color, the vulcanization of which is effected gradually, by means of a slow and progressive elevation of temperature, and lasts about four hours.

In telegraphy, insulating bells are used, suspended on hooks of galvanized iron. The outer surface is polished all over, and presents a thickness of 2½ millimetres, so as to cut off the electric current.

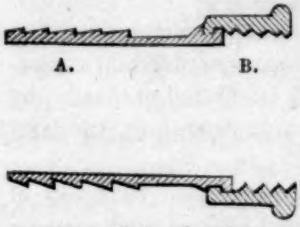
If I were to point out all the applications of india-rubber to surgery and ordinary uses, I should become involved in an endless nomenclature utterly at variance with the object of this brief memoir.

New Method for the Commercial Preparation of Oxygen.—Mr. J. A. Wanklyn of London, observing that copper oxide gave up easily its oxygen to barium oxide to produce barium peroxide, proposes to utilize this property in connection with the fact that metallic copper when highly heated, becomes oxidized to copper oxide, for the economical preparation of oxygen from atmospheric air. The barium oxide is mixed with at least half its weight of copper oxide, placed in an iron retort and heated to redness, a jet of steam being blown in. The barium peroxide at first formed gives up its oxygen, and becomes oxide again. Atmospheric air is then blown into the retort, (the steam being stopped) which again, through the mediation of the copper oxide, oxidizes the baryta to peroxide. This is then

decomposed by steam, as before. Instead of baryta, caustic lime or manganic oxide may be used, or a mixture of the latter with lime or baryta.

New Hose Coupling.—Mr. R. Grimshaw has introduced a new hose coupling intended to preserve the butts of the hose, and constructed by a method which greatly reduces the cost.

In the ordinary hose coupling, the thimble or shank which passes through the hollow nut, has a flange against which the main portion of the nut presses when screwed up, but there is nothing to prevent the nut from sliding back against the hose when unscrewing, and thus injuring it. To prevent this, another flange has sometimes been placed behind the hollow nut and held in place by a pin or other contrivance, but this makes the coupling both heavy and costly.



In Mr. Grimshaw's method this thimble A is cast with two flanges upon it, forming a groove, which is nicely cleaned, or if necessary, turned smooth in the lathe. The surface of this groove is then coated with black wash, the thimble placed in a properly prepared mould, and the nut B cast around it, the flange of the latter being formed in the groove.

The black wash prevents contact of the molten metal with the metal of the thimble, and on being rubbed out, leaves sufficient clearance to allow the nut to turn freely.

Immense Photographs.—There is now on exhibition in Paris, says the *Revue Industrielle*, the two largest photographs which have been made since the introduction of the art. One of these photographs represents the principal facade of the new Opera, the other one of the bronzes—the Departure, by Rude—of the Arc de Triomphe de l'Etoile. Each of these prints measures 4 feet 3 inches in length and 3 feet 4 inches in height. They were obtained in one single piece, by well-known processes, and with the aid of a large and specially constructed camera. Except in some of the effects of perspective which perhaps are not reproduced with absolute fidelity, especially the portion representing the dome of the grand Opera, which appears, on the photographs, to crown the facade instead of being in a plane further back, all the lines of the pictures are of remarkable excellence; the mouldings, the busts, the medallions, the inscriptions and even the minutest details being reproduced with rare perfection. The attempt is being made to secure pictures even larger than this.

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